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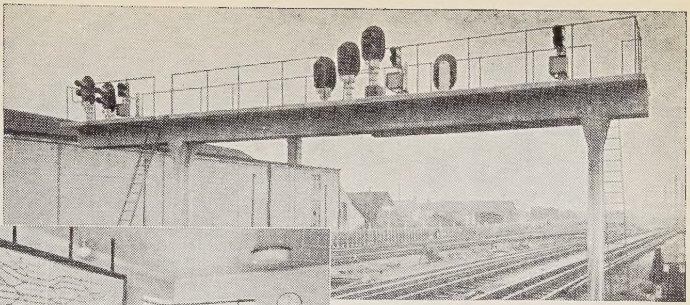
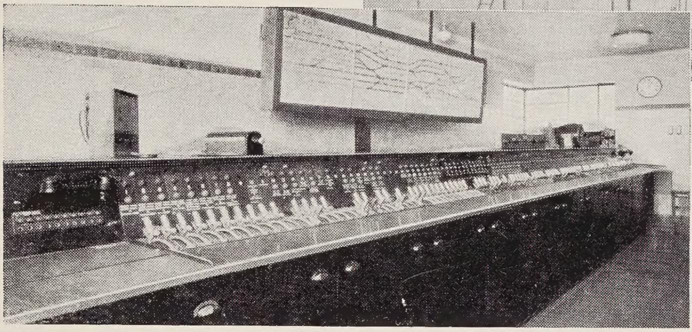
(English Edition)





On London's Underground Railways, Westinghouse Signal equipment has been extensively installed since the first trial installation in 1903.

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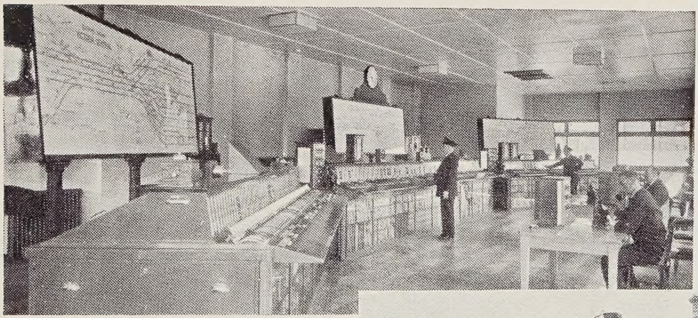

Many years of efficient service can be credited to the Westinghouse Signal equipment which is installed on the extensive electrified passenger lines of the Southern Region, British Railways. These include the large and busy terminal stations of Waterloo, Victoria, London Bridge, etc.

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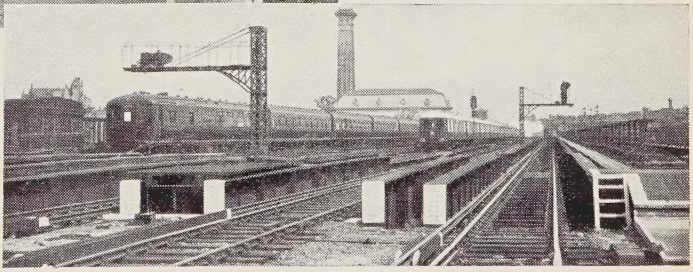

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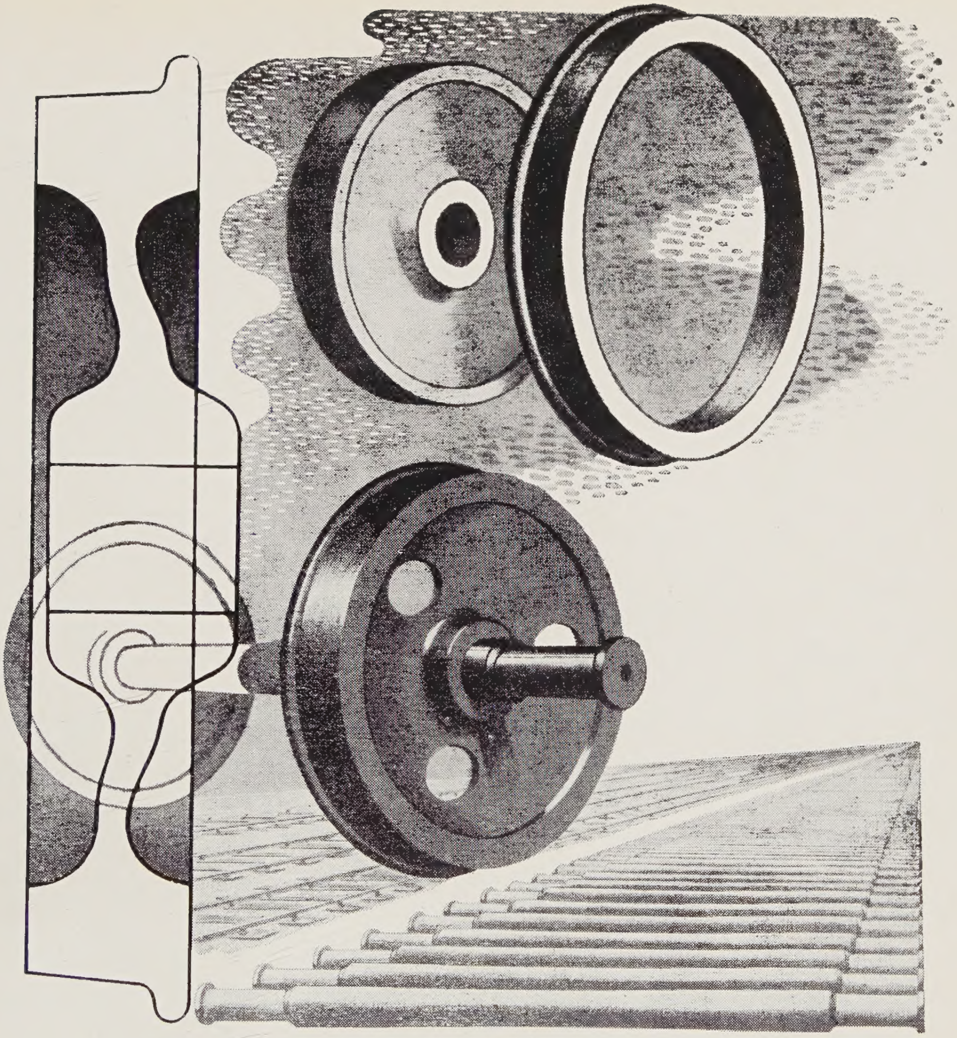

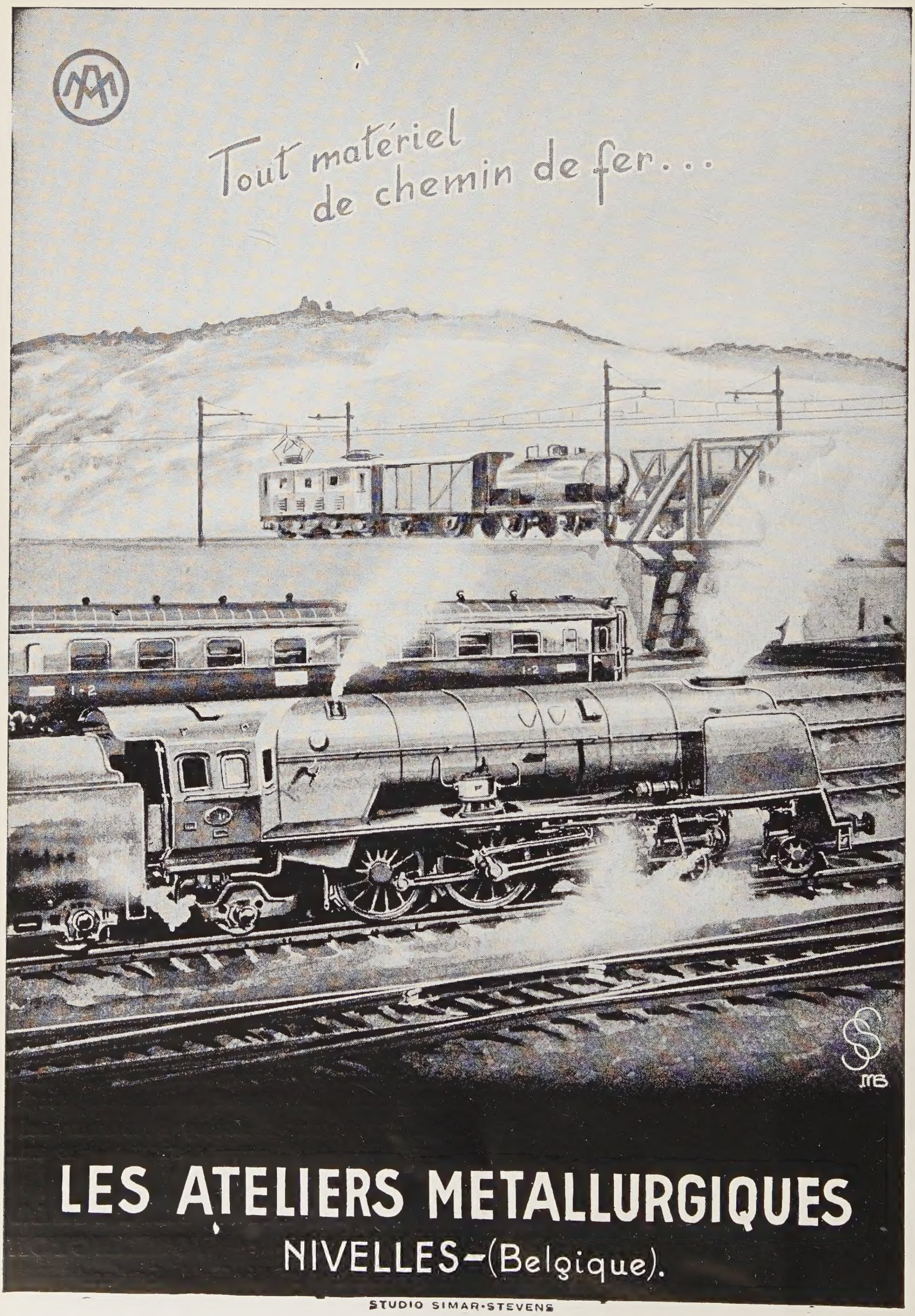
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MONTHLY BULLETIN

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Note. — This contents sheet is appended to the BULLETIN to be cut out, pasted on slips and used for the catalogues.

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HOFFET (Ch.). — **Comparative study of the different types of transmission between motors and axles of electric locomotives, electric motor coaches and Diesel-electric railcars. — Effect on the tracks of the types of bogies and systems of motor suspension.** (Question VI, 15th Congress). Report *(Austria, Belgium and Colony, Denmark, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Sweden, Switzerland and Syria)*. (8 000 words, tables & fig.)

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Bull. of the Int. Ry. Congr. Ass., No. 8, August, p. 1657.

MARGUERAT (L.). — **Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. Future prospects of the prestressed concrete.** (Question I, 15th Congress). Report *(Belgium and Colony, Denmark, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Switzerland and Syria)*. (20 000 words, tables & fig.)

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CHAN (G.). — **Improvements in the construction of rolling stock (motor and trailer) in view of increasing the mileage between repairs : solid wheels or with tyres (metal used for the tyres and solid wheels, behaviour in service); axleboxes; wearing and friction metals; springs (qualities, shape, manufacture).** (Question V, 15th Congress). Report *(Belgium and Colony, Denmark, France and French Union, Luxemburg, Norway, Netherlands and Colonies, Poland, Switzerland and Syria)*. (34 000 words, tables & fig.)

Vol. XXVII. — No. August 1950

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621 .337]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION VI.

Comparative study of the different types of transmission between motors and axles of electric locomotives, electric motor coaches and Diesel-electric railcars. — Effect on the track of the types of bogies and systems of motor suspension.

REPORT

(Austria, Belgium and Colony, Denmark, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Sweden, Switzerland and Syria),

by Ch. Hoffet,

Ingénieur, Chef de section à la Division de la Traction et des Ateliers de la Direction Générale des Chemins de fer fédéraux suisses, à Berne.

SUMMARY.

A. Introduction.
B. General remarks.
C. Axle drive arrangements.
D. Bogies and suspension.
E. Conclusions.
F. Index to bibliography.

A. Introduction.

At the enlarged meeting of the Permanent Commission of the International Railway Congress Association, held in Lisbon in 1949, Section II, under the Chairmanship of Sir Cyril Hurcomb, discussed the special report prepared by M. d'Arbela from the reports of MM. Dr. E. Meyer and Ch. Sthioul and also Mr. G. A. Dalton on Question 2, which was « Electric locomotives for express trains (120 km/h. [74 m.p.h.] and over); discussion of adopted and projected types ». The final text of Conclusion No. 3 referring to this report, as it was adopted by Section II. is as follows:

« 3. The numerous systems of axle-drive in use appear to be still in a state of evolution, although constructors appear to prefer solutions allowing a certain liberty of movement between the ensemble of the toothed wheels in mesh and the axle or else the motor-shaft.

» *The nose suspended motor is still in use and it is even being adopted in certain countries for new stock now being designed.* » (*9*) [1]

[1] The figures in parenthesis and printed in italic relate to the list of publications in the index of bibliography given at the end of the report.

It would therefore seem that constructors in the various countries are divided into two groups, one favouring the use of nose suspended motors, the other favouring motors fixed rigidly to the frame. With the purpose of explaining the grounds for these two opinions, it was decided to include in the Agenda of the Session to be held in Rome in 1950, Question 6, entitled similarly to the present Report.

A detailed questionnaire was sent to 56 Railway Administrations, 32 of which have sent replies. The replies of 14 Administrations only, covering eight countries and their colonies, were sufficiently detailed to serve as a basis for the preparation of this report.

This low proportion indicates that most of the Administrations which have not replied, or whose response has been negative, do not possess vehicles which come within the scope of this questionnaire. The following notes cover experience obtained in Germany [1], Austria, Belgium, Denmark, France and Colonies, Norway, Netherlands and Switzerland.

B. General remarks.

I. — The task of the Reporter was to establish the points of view of the Administrations in question regarding the efficiency of transmission mechanism from the electric motor to the driving axles of locomotives and electric or Diesel-electric rail motor coaches and to compare the different systems. In addition, most of the vehicles considered have driving bogies, the construction of which depends more or less on the method of driving the axles, and it is therefore relevant to examine the construction of these bogies. It appears logical to deal with these two subjects concurrently since it is generally admitted that forces on the track created by a vehicle in movement are related to the functioning of these two factors. For this reason we have considered it desirable to extend the scope of our report to include this point.

The behaviour of a vehicle on the track also depends, inter alia, on the following factors :

a) state of the track;

b) speed;

c) state of the vehicle;

d) suspension of the vehicle;

e) inertia of the moving masses and from this, the axle-load;

f) interior and exterior forces, operating either :

1) longitudinally on the drawhooks (tractive effort), or

2) transversely, as for example, from centrifugal force, or

3) vertically, as reactions from the traction couple or the braking couple.

Usually, the standard of behaviour of a vehicle on the track is judged on the basis of subjective observation. It is quite natural that the running behaviour of a driving vehicle should be judged from the viewpoint of the driver, whose position is well defined. However, observations made in this way do not give a true idea of the vehicle under consideration. In fact, it is well known that the behaviour of a two or four axled vehicle is appreciated quite differently by passengers according to the position they occupy, either in the middle of a vehicle, or overhanging the axles. There are 1′B-B1′ locomotives, with two driving bogies, the running of which is criticised by crews. The driving cabs of these locomotive have 1.10 m (3′ 7 5/16″) overhang in relation to the bearing points of the bogies. Other locomotives, type 1′C-C1′ of a general arrangement similar to the previous ones, but with a driver's cab to the right, or slightly behind the body bearing are considered excellent. The behaviour of the bogies and axles of these two types of vehicle is, however, identical, and the forces applied to the track are the same. Other locomotives, with a rigid frame, type 2Do1, with bogie and bissel

[1] Information obtained directly by the Reporter.

truck, are considered by crews to be very smooth running. The Permanent Way staff, on the other hand, are of the opinion that these latter engines demand much more track maintaining than the first two types mentioned. These examples prove that to judge the running of a driving vehicle it is necessary to take observations in various parts. Observations made during trials or in traffic have a strictly subjective nature. It is beneficial to supplement them by means of recording apparatus such as vibrographs, seismographs or other mechanical means. The assessment of diagrams obtained in this way is however very difficult, because it is not always possible to link up the diagrams with the reactions of the observer. Indeed, it is sometimes impossible for a specialist who was not present at the test to deduce from the recordings the result of the trials without the assistance of the observers who took part. In our opinion, it is therefore not sufficient to judge the riding of a vehicle on observations made from a single point (driver's position); on the contrary, it is necessary to analyse the relative movements of all the elements which may have a good or bad effect on the observations made by the driver. Some of these movements will be compensated by reciprocation, others will be amplified or increased. Amongst the relative movements to be analysed are those of the body and the bogie, the frame and the axleboxes, the play of the springs, the pivoting of the bogies and the movement of the wheel in relation to the rail. Analysis of all these movements calls for much work and numerous specialised staff, which only the large Administrations can find. Up to the present, several of the Railway Administrations covered in this report have undertaken trials to investigate these questions. It appears to us that it would be advantageous to co-ordinate these investigations to avoid the waste of effort which is inevitable in dispersed individual trials.

Several international groups had already started on these problems in 1939. It is desirable that they should take up again the investigation which was interrupted by events. The task is too great to be carried out by a small group alone. The purposes of such co-operation would be to establish rules to allow prescribing general conditions to be observed in the construction of a motor vehicle, to ensure the best running qualities. In fact, it has not so far been possible to forecast with any accuracy whether the running stability of a motor vehicle under construction would be good or bad, despite the efforts of constructors. It is possible to study in the laboratory all the phenomena which influence the functioning of the Diesel motor or electrical equipment which will be mounted in the same vehicles. The most difficult question to resolve is that of relative movement between rail and wheel and the forces set up between these two items.

II. — The questionnaire submitted to the Railway Administrations was very detailed. The replies to certain questions of a general nature have allowed us to treat in proper proportion the devices contemplated. The construction of the vehicles covered by this report is still in development. This is proved by the small number of systems on which these vehicles are working. It is clear that the future will produce new arrangements which will replace those now in use, and will spread to those systems which now use only steam. Nevertheless, it would be premature to judge the direction in which constructors will move. The factors which bear on the development of construction are too numerous and often of a very ephemeral nature. Large scale electric traction is still of too recent origin to allow it to be said that the construction of the rolling stock is already « crystallised », as seemed to be the case some thirty years ago with steam locomotives.

Some of the questions were posed as a result of difficulties which had arisen in service and of which we were aware. The replies received have shown that the same

TABLE I. — Main characteristics of ele

No.	Country	Administration	Type of locomotive	No. of locomotives	Date in serv of firs locomo
1	2	3	4	5	6
1	*Germany*	DB	1′ Do 1′	30	1935
2	»	»	Bo′ Bo′	113	1932
3	»	»	Co′ Co′	69	1940
4	*Austria*	OeBB	1′ Do 1′	7	1940
5	»	»	Bo′ — Bo′	38	1938
6	»	»	Co′ — Co′	44	1940
7	*Belgium*	SNCB	BB	20	1949
8	»	»	BB	3	1950
9	»	»	BB	3	1949
10	*Denmark*	DSB	2 Bo 1	2	1929
11	»	»	2 Do 2	2	1932
12	*France and colonies*	S.NCF	2 Do 2	16	1934
13	»	»	2 Do 2	6	1935
14	»	»	2 Do 2	72	1926
15	»	»	Co — Co	2	1949
16	»	»	Bo — Bo	20	1948
17	*France and colonies*	SNCF	A1A — A1A	100	1946
18	»	»	Bo′ — Bo′	7	1934
19	«	»	1′ Do 1′	1	1937
20	»	»	2Co2 — 2Co2	1	1937
21	»	»	2Co2 — 2Co2	1	1937
22	*France and colonies*	Franco-Ethiopian	A-1A — A1A	12	1950
23	»	Algerian	A1A — A1A	15	1946
24	»	»	A1A — A1A	25	1947
25	»	»	A1A — A1A	15	1948
26	»	»	Co + Co	30	1932
27	»	»	Bo + Bo	2	1947
28	»	Madagascar	Bo + Bo + Bo	5	1943
29	*Norway*	NS	B′ — B′	24	1922
30	»	»	1′C — C1′	5	1925
31	»	»	(1′C) (C1′)	3	1925
32	»	»	B′ B′	12	1927
33	»	»	1′ Do 1′	16	1940
34	»	»	Bo′ Bo′	3 (+ 25) *	1947
35	*Netherlands*	NS	1′ ABo A 1′	10	1948
36	*Switzerland*	CFF	Bo′ Bo′	50	1946
37	»	»	Co′ Co′	2	und. con
38	»	»	Co′ Co′	2	und. co
39	»	»	Bo′ Bo′	2	1939
40	»	»	1A Bo A1	1	1941
41	»	»	1 Do 1	6	1941
42	»	»	1A Bo A1	6	1944
43	»	BLS	Bo′ Bo′	5	1945
44	»	RhB	C C	15	1921
45	»	»	Bo Bo	4	1947

ax. speed n trials	Total weigth in running order	Adhesive weight	Weight per driving axle	Hourly rating of motors	Dia. of driving wheels	Remarks
7 km/h	8 t	9 t	10 t	11 HP	12 mm	13
150	108.5	78.1	19.5	4 120	1 600	
90	78.0	78.0	19.5	2 990	1 250	
90	108.5	108.5	18.1	4 480	1 250	
145	110.0	78.8	19.7	4 870*	1 600	
90	81.7	81.7	20.4	2 490*	1 350	at the wheel tread
100	118.5	118.5	19.8	4 470*	1 250	
100	81.5	81.5	20.4	2 250	1 350	
125	81.5	81.5	20.4	2 750	1 262	under construction
130	81.0	81.0	20.25	2 850	1 350	
80	57.3	27.0	13.5	576	1 402	Dielsel-electric
100	103.0	52.0	13.0	832	1 402	
150	130.0	80.0	20.0	5 100	1 750	
150	130.5	80.0	20.0	4 740	1 750	
150	131.8	80.0	20.0	4.200	1 750	
175	102.0	102.0	17.0	4 820	1 250	
105	80 (92)*	80 (92)*	20 (23)*	3 100	1 400	* 92 tons in ballast
96	109	72	17.5	660	1 070	
50	—	—	17.0	—	1 120	
60	—	—	20	—	1 260	U.S.A. Diesel-electrics
140	224.5	108	18	3 840	1 510	
140	228	108	18	3 480	1 510	
90	50.4	33.6	8.4	580	840	Diesel-electrics under construction m gauge
105	124.6	84.0	21.0	1 240	1 067	
132	124.6	84.0	21.0	1 240	1 067	U.S.A. Diesel-electrics
96	103.1	69.0	17.2	840	1 067	
75	120.5	120.5	20.1	2 400	1 350	
105	80.0	80.0	20.0	1 760	1 300	
60	61.5	61.5	10.2	735	900	metre gauge, Diesel-electric
70	61.3	61.3	15.3	940	1 425	
60	138.3	107.0	17.9	2 900	1 530	
60	134.5	104.0	17.3	2 800	1 250	
70	66.8	66.8	16.7	1 400	1 530	
110	82.8	60.0	15.0	2.828	1 350	
60	48.0	48.0	12.0	1 000	1 000	* under construction
160	100	72	18	4 480	1 550	
140	56	56	14	2 560	1 040	
140	120	120	20	6 000	1 250	
50	89	89	14.4	1 420	1 040	
120	66	66	16.5	840	1 040	Diesel-electric
120	92.4	59	14.8	1 440	1 230	Gas turbine-electric
135	105.0	79.4	19.8	5 700	1 350	
135	105.0	79.4	19.8	5 700	1 350	
140	80	80	20	4 000	1 250	
50	66.1	66.1	16.5	1 200	1 070	metre gauge
80	46.0	46.1	11.5	1 600	1 070	metre gauge

TABLE II. — **Main characteristics of elec**

No.	Country	Administration	Type of vehicle	No. of vehicles	Date in servic of first vehicle
1	2	3	4	5	6
51	*Germany*	DB	Bo'2' + 2'Bo	17	1935
52	»	»	Bo'2'+Bo'2'+2'Bo'	4	1936
53	»	»	Bo' Bo'	23	1933
54	*Belgium*	SNCB	BB+2—2+2—2+B	12	1935
55	»	»	B—2 + 2—B	8	1939
56	»	»	(A—1)—(1—A) + (A—1) — (1 —A)	1	1946
57	»	»	(A—1) — (1—A) + (A—1) — (1—A)	0/25	1950
58	*Denmark*	DSB	Bo — Bo	62	1933
59	»	»	(2 Bo + (Bo-2)	3	1935
60	»	»	(2-B-B) + (B-B-2)	5	1937
61	»	»	3 — Bo	49	1935
62	»	»	3 — (A—1—A)	10	1934
63	»	»	3—Bo + Bo—Bo	1	1943
64	»	»	3 — (A—1—A)	5	1932
65	»	»	Bo — 2	4	1928
66	»	»	Bo — 2	15	1929
67	*France and Colonies*	SNCF	Bo' Bo' Bo'	20	1937
68	»	»	Bo' Bo'	5	1938
69	»	»	Bo' Bo' Bo'	2	1948
70	»	»	(2—Bo) + (2—2) + (Bo—2)	18	1936
71	»	»	2 — Bo	13	?
72	»	»	Bo — Bo	17	1946
73	»	Gafsa	1A — A1	4	1946
74	*Norway*	NS	Bo' — Bo'	4 (+18)	1945
75	»	»	Bo' — Bo'	34 (+22)	1936
76	*Netherlands*	NS	Bo 2' 2'Bo' + Bo'2 2' Bo'	14 (25)	1942
77	»	»	Bo' 2' + 2' Bo'	4 (15)	1943
78	»	»	Bo' 2' Bo'	28 (79)	1948
79	»	»	Bo' 2' Bo'+Bo'2 Bo'	8 (65)	1948
80	»	»	6 mot. ax. + 12 carr. ax.	9 (18)	1940
81	*Switzerland*	CFF	2 — Bo'	7	1935
82	»	»	2'Bo' — Bo' 2'	1	1939
83	»	»	Bo' Bo'	13	und. co
84	»	RhB	Bo' Bo'	4	1939

iesel-electric railcars and motor coaches.

x. speed trials	Total weigth in working order	Adhesive weight	Weight per driving axle	Hourly rating of motors	Dia. of driving wheels	Remarks
7 km/h	8 t	9 t	10 t	11 H. P.	12 mm	13
120	92.0	56.0	14.0	1 385	950	
120	145.0	73.0	12.1	2 250	970	
85	52.0	52.0	13.0	1 260	1 000	
120	273.7	163.3	20.4	2 170	1 118	
120	128.5	75.8	19.0	1 080	1 118	
140	134.7	67.3	16.6	1 080	1 010	
105	113.3	56.7	14.2	1 060	1 010	under construction
90	55.0	55.0	13.7	520	934	electric MM
120	136.0	77.2	19.3	1 024	966	Jacobs bog. MS
120	190.0	76.4	19.1	1 024	966	Jacobs bog. MB
120	62.0	28.6	14.3	420	970	Diesel-MO
120	60.0	19.0	9.5	420	966	electr. MP
120	126.0	82.8	13.8	780	970	MK/FK
100	59.0	20.0	10.0	250	970	MQ
80	48.0	22.6	11.3	258	970	MR
75	49.0	23.8	11.9	190	970	ML
130	74.0	74.0	12.3	1 580	950	at the wheel tread
130	38.5	38.5	9.7	920	900	at the wheel tread
150	79.0	79.0	13.1	1 200	1 000	at the wheel tread
150	151.0	~ 50.0	~ 12.5	820	900	
110	33.0	33.0	8.2	300	900	
110	48.4	48.4	12.1	640	900	
100	40.0	20.0	10.0	216	850	metre gauge
120	46.7	46.7	11.7	980	970	
70	41.8	41.8	10.5	632	810	
140	209.0	105.4	13.6	820	950	
140	101.0	54.0	13.7	820	950	
140	85.6	55.6	13.9	820	950	
140	112.5	54.5	14.0	820	950	
160	237.0	84.3	16.3	1 350	950	5-car Diesel-elect. set
150	35.0	18.0	9.0	550	900	
150	93.0	45.2	11.3	1 172	900	
110	54.0*	54.0*	13.5	1 600	950	*empty
65	37.0	37.0	9.2	620	850	metre gauge

problems are experienced everywhere and are generally solved in similar ways. Differences in solutions are often due only to the personal preferences of the constructors.

Shortage of time and space has prevented us comparing in detail all the replies to the questionnaire. In the following remarks we believe we have, however, given with sufficient accuracy the main principles followed in general by the Administrations consulted.

III. — In this report we shall consider only the vehicles mentioned in Tables I and II. Some of the vehicles have already been mentioned in the Lisbon Report (Question 2). The figures in parenthesis in this report (......) are the listed numbers of the vehicles as in Tables I and II. We have amplified the information received from the Administrations after consulting the publications mentioned in the bibliographical index mentioned at the end of this Report.

We have considered it helpful to include in these Tables some general characteristics of the vehicles dealt with, characteristics which do not seem at first glance to have any great influence on the parts under examination. Having regard to the particularly difficult conditions for construction of stock and operation of their lines some narrow gauge systems provide solutions worthy of interest. A note in column 13 of Tables I and II calls attention to this point. All other vehicles are of standard gauge.

The date in service of the first vehicle of any particular type (column 6) is a pointer, in a very general way only, to the development of the constructions in mind. In practice, vehicles of certain types are standardised in order to facilitate operation and maintenance; they are built in large series, despite there being in existence on other systems more modern and sometimes better types. This fact should be taken into account in comparing the different types. In column 7, the maximum speeds on trials mentioned are in the region of 10 % above the maximum speed authorised in service. The load per driving axle mentioned in column 10 is the static load on this axle.

The total number of vehicles considered is 1 477, made up as shown in Table III.

TABLE III.

Distribution of the vehicles examined.

Put into service	Total number	
	vehicles	driving axles
Before 1940 .	875	3 690
1941-1945 . .	86	456
Since 1946 . .	516	2 330
Total	1 477	6 476

The Administrations consulted have a much greater number than those we have reported. Certain systems have not put into service any new types of vehicle since 1940. The vehicles mentioned are only some examples chosen from each system for different reasons, and it is difficult to draw any conclusions based on the various figures reproduced here. The supplementary notes regarding the intentions of Administrations which have been sent to us, however, throw some light on the situation. It is also necessary to bear in mind that in certain countries the war has hindered progress or prevented the use of the high speeds for which the vehicles were built.

It may be pointed out here that certain Administrations have put into service since 1946 a large number of American Diesel-electric locomotives. These are shown by the initials USA in column 13 of Table I. They are different design to European-built locomotives and cannot be omitted

from this survey. At the same time, even if experience allows the adoption of certain features in new constructions, European builders would adopt them only so far as they fitted in with their designs and with operating and financial conditions which are totally different from those on the other side of the Atlantic. When comparing constructions originating in different areas, it is often forgotten that each of them is the result of local conditions, the personal preferences of the builders and the tradition of the systems.

IV. — Amongst the questions which related equally to the transmission from the motor to the driving wheels and to the bogies, we may mention the following :

a) *Maintenance.*

In general, motor vehicles of Administrations consulted are thoroughly overhauled in main workshops after a mileage of 200 000 to 400 000 km (124 000 to 248 000 miles). A special examination can be made between two overhauls; the Diesel motors often demand an intermediate inspection about every 60 000 km (38 000 miles) when worn parts are replaced. In addition, as gearcases are not always oil-tight, some systems are obliged to replace the oil at more frequent intervals and to examine bearings and springs of certain driving parts.

b) *Axleboxes.*

We know that inside axleboxes, as used on locomotives with inside frame plates, have the following decided advantage over outside axleboxes : the guiding forces exerted by the rail on the wheel tyre have the effect of reducing the initial fatigue of the axle under static load; with outside axleboxes these forces increase axle fatigue. Inside axleboxes increase the smoothness of lateral stresses when entering curves. In spite of these advantages, most systems consulted prefer outside axleboxes as construction is simpler, inspection and maintenance are easier and they allow the use of wider motors. However, it may be pointed out that one Administration has put into service locomotives with inside axleboxes in order to reduce weight. Another Administration equips its railcars with inside axleboxes which suit the drive arrangements and facilitate access to the brake rigging and shoes.

c) *Diameter of driving wheels.*

In the construction of steam locomotives, there are empirical rules by which the diameter of the driving wheels can be calculated as a function of the speed, these rules being framed by the necessity for limiting the speed of the axle rotation because of the unbalanced mass of the mechanism; electric locomotives with individual drive are not subject to this limitation. The driving wheels of electric locomotives built since about 1945 have diameters of 1 000-1 400 mm (3′ 3 3/8″-4′ 7 1/8″). A diameter of 1 250 mm (4′ 1 7/32″) appears to be becoming general even for the highest speeds. No Administration specifies a wheel diameter as a function of the load. There is no experience on which to base an opinion as to whether the track is more highly stressed by small wheels than by large ones, as would be expected on a theoretical basis. One system also remarks that track which was laid on a spongy sub-soil was more heavily treated as the loading of the driving axles was increased. Another system notes that tyre wear was heavier on smaller diameter wheels than on large diameter wheels, because for the same distance, the number of revolutions is higher.

In general, there is a noticeable tendency to reduce the diameter of driving wheels despite the reluctance of some Administrations to introduce new types of tyres.

It is probable that this reduced diameter is dictated mainly by the decrease in weight and also the belief that large guiding wheels will not follow curves.

d) *Position of the centre of gravity of vehicles.*

It is interesting to note that, contrary to the development of the steam locomotive,

in which the centre of gravity was, about 1850, placed as low as possible and climbed gradually, over about a century, to a height of approximately 2 m (6′ 6 3/4″), electric locomotives of several Railways have the opposite tendency. One system for example had the centre of gravity in the latter located about 1 650 mm (5′5″) above rail level in 1930 and this has been brought down to 1 050 mm (3′ 4 11/32″) in 1945 with the purpose of increasing speed through curves, whilst reducing the risk of overturning from centrifugal force. This tendency has resulted in the motors being set as low as possible. There is no disadvantage to the motors from this, provided that the forced ventilation directs the air from the body to the motors and provided that the suspension of the motors, bogies and body is improved to reduce the lateral shocks.

e) *Effects of discontinuing steam traction.*

Several Administrations have noted, as advantages of electric or Diesel-electric traction :

1) cleanliness of ballast;
2) lower fatigue of track;
3) reduced track corrosion in tunnels.

On the other hand, they mention increased corrugation of rails and a greater tendency to chamfering of rails on curves. To overcome the latter, several systems have obtained good results by lubricating the rails or tyres by various methods.

C. Axle drive arrangements.

I. — These arrangements are for transmitting to the driving axles the motive effort (or couple). Generally the motor shaft rotates at a higher speed than the axle. The speed reduction is effected through a pair of gears with a fixed axial spacing to ensure perfect meshing and smooth running. For reasons of construction, the motor is wholly or partly suspended from the frame in which the axle has play in a vertical direction.

To avoid heavy strains on the gears, due either to tractive or braking couples or to reaction from track irregularities, it is necessary to introduce a resilient member into the transmission system. This resilience can be located either in the gears or in one of the shafts to be linked up or in the parts fixing the motor to the frame, as in tramway's motors.

The different systems of transmission from the traction motors to the driving axles of electric or Diesel-electric vehicles have been described in numerous articles; we will confine ourselves to mentioning the works of Dr. E. MEYER and Ch. STHIOUL (*9*) and Ad. M. HUG (*2, 7*). All these systems can be arranged broadly under the four headings shown in Table IV.

We may recall the characteristics of these four groups, which in principle fulfil the same functions, viz :

a) the transmission of effort from the motor to the axle and

b) the absorption of vertical play of the driving axle.

1. *Nose suspension, rigid gears.*

The traction motor rests partly on the driving axle through bearings and partly in suspension from the frame through springs or rubber pads. The transmission of the motive effort is by means of rigid gears, which can be arranged either on one side of the motor or on both sides. As a rule, the motor is held laterally by bushes on the axle and, in one case, by links fitted with silent blocs.

2. *Nose suspension, resilient gears.*

Same arrangement as above, except that the gears include a spring arrangement to provide the necessary resilience.

3. *Frame suspended motor; flexible or articulated transmission.*

The motor is fixed solidly to the frame. To allow for the movement of suspension springs and hence the relative movement

of the driving axle and the frame, the gears include a cardan mechanism, either as a parallelogram or with a spring element.

4. *Rods.*

Where the number of axles to be driven is not the same as the number of motors, it is advantageous to use a rod arrangement which works on an intermediate axle. In certain cases the number of motors can be the same as the number of driving axles. The gears often include an arrangement of springs.

The Railways consulted have no motors without gears as they would be too large for the speeds and powers required nowadays. It is not the purpose of this report to criticise or compare the different solutions used under the same grouping, but only to examine the groups themselves.

The choice of drive depends on the following factors :

a) power to be transmitted;
b) axle load;
c) maximum speed;
d) diameter of driving wheels;
e) country of builder or Administration;
f) period of going into service.

In fig. 1 we have shewn the distribution of the systems examined in relation to the transmitted effort per axle and the date in service of the first vehicle equipped. This diagram clearly demonstrates that except for nose suspension with rigid gears, put into service before 1940 (3, 6) the tendency is to use this system up to 300 HP only. Nose suspension with resilient gears is used up to 750 HP and fully suspended motors with flexible transmission from there up to 1 400 HP. The Administrations consulted have not yet been able to determine the limits of use of each of these systems.

The diagram of fig. 2 shews that nose suspension arrangements are used in vehicles which run at speeds almost as high as those with flexible gear transmissions. It would therefore seem that the use of one or other of the systems is at present limited only by the power to be transmitted.

If the diameter of the driving wheels is in excess of 1 500 mm (4′ 11 1/16″) a fully suspended motor is required.

TABLE IV. — **Distribution of transmission systems covered in the Report.**

System	No. of vehicles fitted			No. of axles fitted		
	before 1940	1941-1945	since 1946 and under construct.	before 1940	1941-1945	since 1946 and under construct.
1. Nose suspension, rigid gears.	539	41	217	2 262	266	858
2. Nose suspension, flexible gears	56	—	215	224	—	1 118
3. Fixed motor, flexible transmission . . .	221	45	86	922	190	356
4. Fixed motor, rod transmission.	59	—	2	282	—	12

II. — From the replies received, the various methods of drive seem to have the following advantages and disadvantages :

1. *Nose suspension; rigid gears.*

This is the simplest and cheapest solution initialy; it allows space for the motor over almost the full width between the wheels. However, the large unsuspended mass of the motor exerts undesirable forces on the track, comparable to those of the

unbalanced mass of mechanism of a steam locomotive. The Administrations which use it on lines hitherto operating steam traction have not, however, recorded any heavier track maintenance which could be attributed to this type of transmission. On the other hand, it is noted that shocks arising from the track frequently cause damage to the motor.

It can be pointed out that one system put into service in 1940 a large number of locomotives equipped with 750 HP nose-suspended motors and rigid, bilateral gears (3, 6). For economic reasons, this Administration has been content with this system of transmission in spite of its drawbacks (strain on tracks and vibration) (*20*). On rail motor coaches, commutation would not be so good with nose-suspended motors as with fully suspended motors. It would seem, however, that this Administration intends in future to equip its new stock for single-phase lines, 16 2/3 cycles, with resilient gears. Another Administration has replaced rigid gears on several railcars with nose-suspended motors by flexible gears. At the same time, some electric shunting tractors of 125 HP which were equipped with a nose-suspended motor and flexible gears will in future be ordered with rigid gears as these are cheaper.

A certain number of Diesel-electric locomotives of American origin are fitted with nose suspended motors with rigid gears. The transmitted power per axle does not exceed 310 HP and the maximum speed is 132 km/h. (82 m.p.h.) (17, 23, 24, 25).

Certain Administrations have replaced motor suspension springs which broke frequently by rubber springs. Experience is not yet decisive. It would, however, appear that these springs will have to be replaced frequently owing to the premature hardening of the rubber. When starting, the motor may pivot on the driven axle until the springs become solid. This results in a rotation of the armature with an amplitude in the region of 10°. This amplitude, which is desirable to spare the commutators, is quite in line with that of fully suspended motors (1°31′ to 31°).

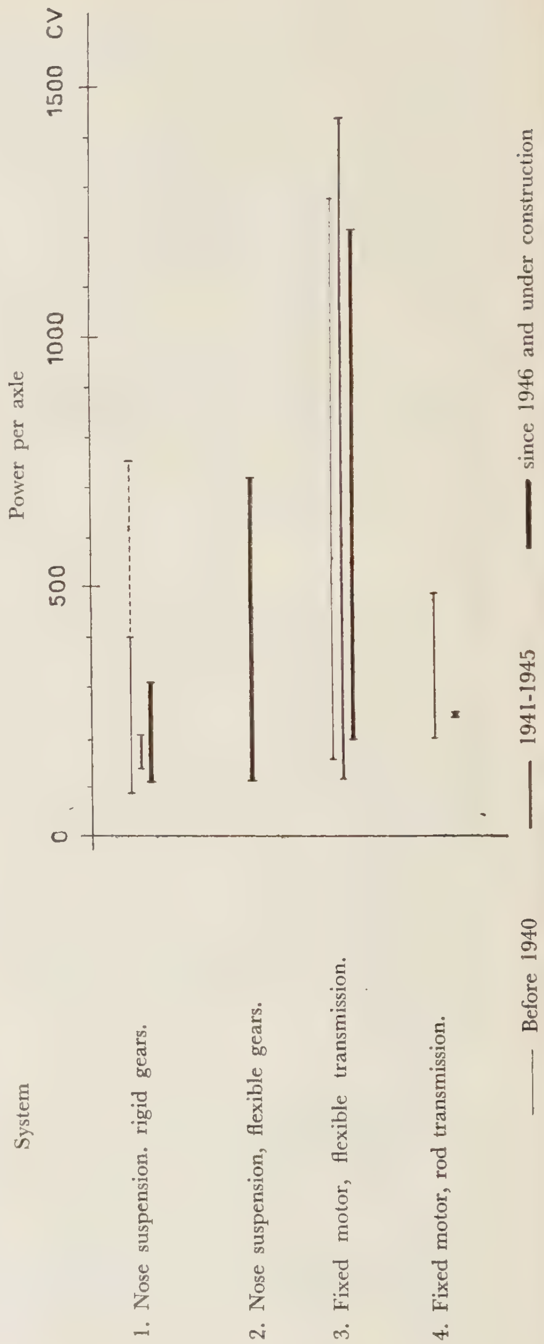

Fig. 1.

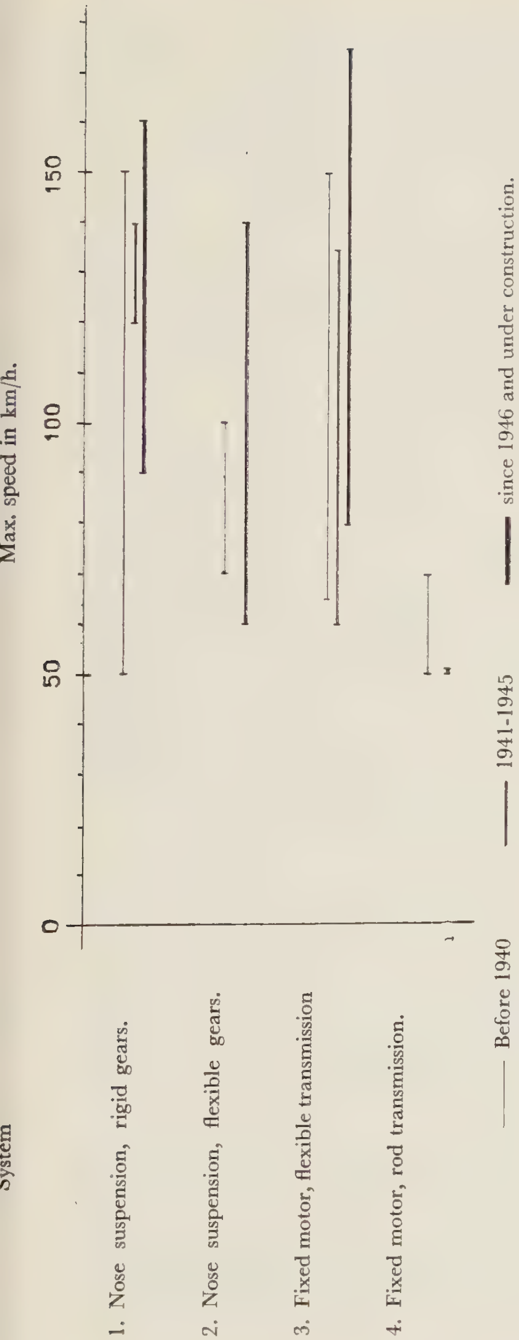

Fig. 2.

2. *Nose suspension; flexible gears.*

Some Administrations have provided flexible gears in place of rigid gears on vehicles equipped with nose suspended motors. They have decided on this difficult conversion so as to reduce maintenance costs of the vehicle so modified. In effect, owing to the flexibility of the new arrangement, breakages of gear wheel teeth, which were previously frequent, have been obviated.

In general, those Administrations which continue to use nose-suspended motors in new stock provide them with flexible gears.

We would refer to the last sentence of para. 1 above, with regard to the rotation of commutators. With resilient gears, it is easy to double the amplitude of this rotation.

3. *Fully-suspended motors.*

Of all the solutions found, the fully suspended motor has the highest primary cost of fitting. At the same time, the advantages are such that several Administrations no longer accept nose-suspended motors with either rigid or flexible gears. Certain transmission systems with fully-suspended motors seem to demand a minimum of maintenance, which justifies the confidence of the Administrations which have adopted them. Some hollow shaft transmissions are not absolutely homokinetic. The difference in speed of rotation of the two concentric axles is however too small to need taking into account in present constructions. No Administration has been able to give figures on this subject based on tests, and time has been insufficient to allow us to calculate the amount of these irregularities. In some systems, the drive springs support a part of the axle load; they are then subject to supplementary fatigue due to their function as supplementary bearing springs. Breakages of these springs are frequent.

One Administration, considering the nose-suspension is not satisfactory, has stated that present types of articulated

transmission are too complicated and that they restrict unduly the movement of the axles from the underframe bearing springs.

Some Administrations have endeavoured to replace the springs in the gears, which break frequently, by silent-blocs. Trials are not yet concluded, but it would seem that premature hardening of the rubber will be an obstacle to success in the trials.

Conical gears have not given satisfaction for high-power transmissions.

4. *Rods.*

Rod transmission has frequently been used in the early stages of electrification on standard gauge lines. This method, probably derived from the construction of steam locomotives, has certain advantages. It permits the use of a number of traction motors less than the number of driving axles and is, in this case, cheaper than individual drive. Coupling of the driving axles reduced the risk of slipping. At the same time, the maintenance costs of this type of transmission are high. In the first case, the tyres must be turned to the same diameter to avoid dangerous stresses in the rods or slipping of wheels. Also, the rod bearings must be renovated frequently and very carefully regulated. Finally, oil consumption is very high. Rod coupling is therefore used only in exceptional cases. In Switzerland, for example, new shunting locomotives are now being constructed with the same mechanism as was standardised some 20 years ago (38). These are less complicated than others proposed during recent years. Tractors of 125 HP with nose-suspended motors are also provided with rods. The maximum speed of these vehicles is 50/60 km/h. (31/37 m.p.h.). Although the results obtained with numerous rod-coupled locomotives built 25 years ago, and running at 100 km/h. (62 m.p.h.) have been favourable, this system of drive has everywhere been abandoned on high-speed locomotives because of maintenance costs. Rod transmission ensures good utilization of the adhesive weight; it is therefore indicated for shunting locomotives.

Teeth of gear wheels are either straight or helicoidal, according to the Administration. Except in single-sided, rigid transmission, in which the effect of lateral thrust is to be feared, the tendency is to use helicoidal gears with a 6° angle in relation to the centre line of the axle.

III. — From the replies received, it emerges very clearly that the modifications and improvements made to existing transmissions are dictated by the need to reduce maintenance costs. In new stock, attempts are also being made to improve running and so reduce maintenance. Amongst the parts which have not always been satisfactory as regards robustness, or resistance to wear, we may mention transmission springs, rubber buffers and spring bearing plates. Transmission springs are often subject to combined stresses, difficult to assess in advance. It is not usually possible to strengthen the springs afterwards.

In one case, after the transmission springs were re-inforced, the elasticity was reduced below the permissible limit. Since then, the springs no longer break, and the defects which could be expected in consequence of this relaxing of an established rule have not arisen. Geared rims and pinions with insufficient thickness, particularly those of nose-suspended motors, have broken in service.

The problem of lubrication is of absolute importance; it seems to have been solved in some recent constructions. On the other hand, some gear cases are not yet sufficiently leak-proof, and demand frequent replacement of lost oil.

One Administration is attempting to provide pressure inside the gear cases to prevent entry of dust.

IV. — In general, the tendency is for future high-speed locomotives to have total adhesion. The motors will be entirely suspended, or in some cases nose-suspended and fitted with flexible gears. Administrations wich have already used flexible transmissions are not returning to nose-suspen-

sion and rigid gears except for low powers and moderate speeds. The choice of more complicated and costly solutions is not decided only by theoretical considerations, it is also based on practical experience. One Administration is, however, to put into service a locomotive with nose-suspended motors, rigid gears and 1 350 mm (4′ 5 1/8″) wheels. It is proposed to convert these machines to 140 km/h. (87 m.p.h.) if they do not give satisfaction. For high speeds also, the diameter of the driving wheels varies between 1 000 and 1 350 mm (3′ 3 3/8″ and 4′ 5 1/8″) on locomotives and between 900 (2′ 11 1/2″) and 1 100 mm (3′ 7 5/16″) on motor coaches. Some locomotives with carrying bogies form exception to this rule; their driving wheels will have a diameter of 1 750 mm (5′ 8 7/8″).

Manufacturers are still seeking to improve the details of the driving arrangement and to use new materials (for example, rubber) to reduce vibration, wear and maintenance. In general, the tendency is to set traction motors as low as possible to reduce the risk of overturning by centrifugal force when running through curves; this arrangement also provides more space for the fittings inside the locomotive body, or for furnishings inside motor coaches. However, lateral shocks increase in strength, unless an adequate suspension is chosen.

D. Bogies and suspension.

I. — In this section, we shall deal with driving bogies and their suspension. Designs are very varied and consist of different combinations of often similar components. It is not so simple to classify the various types of bogie as was the case with drive arrangements for axles. However, we can subdivide the bogies used in the vehicles mentioned in Tables I and II as follows :

a) bogies with two driving axles;

b) bogies with three axles, two driving;

c) bogies with three driving axles.

Following the method of setting the body on the bogie, we find in these three groups, bogies :

1) with swing bolster;
2) without swing bolster.

The load of the body is transmitted to the main frame :

in the first case by springs;

in the second case directly by the pivot and by side bearings, where these are used.

Certain rail motor sets have bogies arranged between two bodies. A centre pin supports the two juxtaposed ends of these bodies. In other similar sets the bogies have two pivots, each serving one of the two bodies. These bogies have the disadvantage of being more difficult to withdraw than those under one body only. From the main frame, the load can either bear directly on springs solid with the axleboxes or be transmitted to the latter by an intermediate equaliser and springs.

The springs themselves may be helical or laminated. According to the design, there are opposed leaf springs, twin springs or combinations of various kinds of springs.

The guiding of the body is effected by means of a flat or spherical socket or a centre pin.

When suspension is by a spring bolster body oscillations are damped by gravity.

An interesting arrangement is the C_0-C_0 locomotive shown in pp. 246-7 of the 1949 Congress Bulletin. The body is carried on each bogie, on links with spring recoil (15).

The frame can be cast steel, or plate, profiled and rivetted or welded. The latest designs are of welded plate to form a tubular construction.

II. — The design of driving bogies was based on that of carrying bogies, with a driving motor mounted inside. During the years, they have been modified as a result of the increased speed. The construction of the bogies is governed by the size and permissible axle load. To overcome the effect of these restrictions, builders have

created designs which at first sight appear to be complicated. For example, to save space the laminated springs, oscillations of which are damped naturally by the rubbing of the leaves, have been replaced by helical springs, to which dampers have been added.

The various details concerned in the design of the bogies may be noted as follows :

a) Apart from one type (*8*), all express coaches under construction are provided with swing bolsters. Motor coaches are also similarly equipped. One Administration, for experimental purposes, blocked up the swing bolster of a vehicle; the running was noticeably worsened and it was necessary to restore the correct functioning of the bolster. In general, Administrations recognise the advantages of swing bolsters.

b) Usually, vehicles do not have dampers. Several locomotives built during recent years are provided with dampers for helicoidal suspension springs; other locomotives have side dampers to prevent hunting of the bogies, comprising side rubbing plates or a mechanical spring arrangement. The coupling of two bogies set close together in certain locomotives is also used to damp hunting movements. One Administration states that dampers are desirable at speeds exceeding 100 km/h. (62 m.p.h.).

c) New high-powered locomotives are fitted with holding-down devices, either by compressed air apparatus, by one bogie bearing on the other, or by the provision of two bearing points arranged in two different transverse planes of the same bogie. These devices are useful when the motor couple lifts the axle guides by about 10 - 20 %, when starting under difficult conditions. At the same time, it often happens that these devices are not wisely used, furthermore, their application is not always to be recommended.

d) Several new locomotives have been equipped with a recoil arrangement intended to correct the position of bogies on straight track (36). These arrangements would appear to have some advantages.

e) The links from laminated suspension springs to the body are often sloped in the transverse plane at an angle which may vary between 7° and 13°. This angle depends on the general arrangement of the suspension of the vehicle, and can usually be settled only after running trials. One Administration prefers parallel links and fits the swing bolsters with dampers.

f) Administrations generally prefer outside axleboxes. Roller boxes, of higher cost, are used in all countries consulted for rail motor coaches. Opinion on their use for locomotives is however divided. If they are not overloaded these rollers behave very well in service. Their resistance to movement is very low. New locomotives, which are not fitted with roller bearing axleboxes, have plain bearings with mechanical lubrication (Isothermos, Athermos, Friedmann, Peyinghaus, etc.). The axleboxes of standard type with lubricating pad are used only on low speed vehicles or when space is not available for roller bearing or mechanically lubricated boxes.

One Administration is to undertake trials with axleboxes in which the springs are inset between the bearings and the boxes, with the aim of reducing lateral shocks.

g) Sets of driving wheels are not balanced in the same way by each system. Some prescribe static and dynamic balance, some static balance only and others no balancing at all; the latter are satisfied with the calculated balance.

h) Except for some light motor coaches, which have drum brakes, all the vehicles covered by this Report are fitted with brake shoes which are more powerful and reliable.

III. — Good running of a bogie vehicle depends amongst other things on the method of linking the bogies. On motor coaches, the spacing of the bogie pivots is usually too great to allow fitting a special arrangement, for which space is insufficient. The body serves in this case as the only link between the bogies. On the

other hand, the spacing of locomotive bogies is generally much less. The bogies can then be linked by drawgear to which the buffers can sometimes be attached, the whole being flexible. In this case, one of the two bearings of the body on the bogie (pivot, socket or side bearings) can be provided with longitudinal play to facilitate have the same angle, in relation to the track, of thrust α. Diagram *b* shows a vehicle with the two bogies linked by a rigging T, which acts as a transverse coupling without initial play. This arrangement was used by ENGERTH 10 years ago (*10*). Only the flange of axle 1 is in contact with the inner surface of the rail, with which it

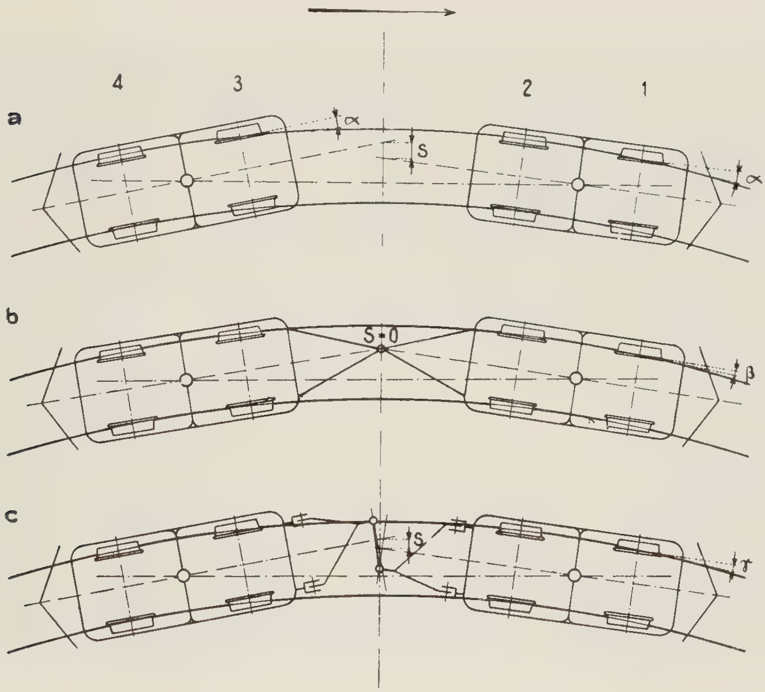

Fig. 3.

running on curves. It is also very useful to provide locomotives (particularly those intended for use on lines with numerous curves) with transverse coupling to conjugate the pivoting of the bogies. The operation of this device can be clearly seen in fig. 3.

Diagram *a* shows a vehicle without transverse coupling running on curved track. The two bogies align themselves in identical fashion on the track and axles 1 and 3 forms an angle of thrust β, much more acute than the angle α of diagram *a*. Arrangement *b* has the drawback of hindering running over points and S curves. For this reason it is necessary to give the transverse coupling a little initial lateral play « S » and provide a spring to give it the necessary flexibility for smooth running over obstacles. The arrangement shewn in diagram *c* has proved its worth. It is used in many new locomotives in service and under construction (36, 37, 38,

39, 43, 45) (*). Its use reduces very considerably the wear on tyres of leading wheels and therefore favourably affects the running of the vehicle equipped. One Administration successfully uses an arrangement for the same purpose on a motor coach. The device comprises a longitudinal shaft pivoting in bearings fixed to the body. Two bars fixed at the ends of the shaft are linked to the inside headstocks of the bogie frame.

IV. — *a*) Amongst the means used to reduce the wear of rails and wheel tyres we can mention :

1) lubricators, of which innumerable types have been made during the past ten years (*40*);

2) increasing the wheelbase of bogies.

It can be stated that in several countries, after the adoption of electric traction, a considerable increase has been noted in wear of rails and wheel tyres of vehicles running on curved lines, compared with steam traction. This increase is due, partly to the absence of grease-laden vapour from the locomotives, partly to the increase in running speeds and axle loads as well as the use of electric driving vehicles with a bogie wheelbase shorter than the total wheelbase of the steam locomotive. This automatically resulted in an increased angle of contact of the leading wheels of electric vehicles compared with that of steam locomotives, and consequently increased wear. However, the axles of a bogie cannot be spaced more than 3 500 mm (11′ 5 13/16″) without exceeding the track gauge, which would give very poor running on the straight.

b) The use of 3-axle bogies has sometimes increased rail wear (*6*). It is known that the presence of an intermediate axle gives rise on curves to supplementary directional forces on the leading axle. To reduce this effect, it is desirable to give the intermediate axle side play. The Administrations have not measured these forces.

c) The misgivings expressed regarding the use of large guiding wheels seem exaggerated when we consider that the old steam locomotives which operated at 90 km/h. (68 m.p.h.) and over had driving wheels of 1 750 mm (5′ 8 7/8″) and no leading carrying axle (*10*). It is rather because of unbalanced mass than because of wheel diameter that leading carrying axles have since been prescribed.

V. — Most Administrations point out that stability of engines decreases when the axles have developed lateral play through wear of tyres and boxes.

Bogies of the various types are usually satisfactory in service. At the same time it can be pointed out that welded designs often show cracks at the end of a fairly short period of service. This arises from the fact that builders have not always taken account of the peculiarities of welding. Only those welded constructions, which have been designed with great care in all details and carried out by competent personnel can sustain the repeated stresses to which they are subjected in service. It must not be forgotten that it is impossible to calculate exactly all the forces which will operate on a Railway vehicle. When a welded construction develops cracks it is not sufficient to fill up the cracks with welding or to strengthen the structure with plates, it is generally necessary to recast the design.

One Administration has improved the running of its rail motor coaches by altering the conicity of tyres from 1 : 20 and 1 : 10 to 1 : 40 and 1 : 20 (51-53).

Several Administrations have replaced guards by joints which can be fitted with silent-blocs.

On one type of B_0-B_0 locomotive, it has been necessary to replace the body bearing springs which were too soft, by harder springs to correct rolling oscillations, which were unpleasant, though less harsh.

(*) See the *Congress Bulletin* (French edition), Apl., 1950, pp. 593/55, fig. 24.

Some Administrations report axle fractures. These are due either to errors of design (driving wheel and gear wheel keyed to the same axle without play between the hubs) or to the type of steel used for the axle (high-tensile alloy steel).

The Administrations consider that the more complicated designs are usually justified by maintenance economies. It is, however, not possible to compare the purchase and maintenance costs for the various arrangements, as these are used in too diverse circumstances. One System only (metre gauge), reports that the maintenance of its C_0-C_0 locomotives with rod drive is three times as expensive as that of B_0-B_0 locomotives with individual drive (fully-suspended motors) and a higher power (*44, 45*).

VI. — As reported under General Remarks, under B 1, several Administrations have undertaken trials to measure stresses on the track due to the passage of trains. Highly technical studies have been published in the various revues mentioned in the bibliography at the end of this Report, and also by certain Administrations themselves. Amongst these numerous works, we may mention those of LANOS, MAUZIN and PFLANZ. These trials have not, however, always been conclusive and reliance has had to be based on theoretical calculation. As an addition to the known publications, we may perhaps mention here some trials carried out in Switzerland to control the working of the suspension components and the running of the driving vehicles generally.

Fig. 4.

The recording apparatus used was as follows :

a) Amsler apparatus for noting relative movement, consisting of a recorder con-

verted from one used for brake trials (figs. 4 and 5).

b) Trüb, Täuber and Co. apparatus, a form of three dimension seismograph (fig. 6) (*37*).

c) Vibrograph apparatus designed specially by the « Fabrique de locomotives de Winterthour ».

With the Amsler apparatus it is possible to record relative movement at eight points on the vehicle simultaneously; for example, the centre line of the coach in relation to

The movement thus recorded on a paper band can be followed in actual size. If necessary, it can be amplified or reduced on the diagram by inserting a reducing pulley in the cable line.

The Trüb-Täuber apparatus records the vibration in, say, the driving cab.

It is advantageous to supplement the recordings by careful observation on the part of an intelligent and experienced observer, whose notes will permit an assessment, over the whole distance of the trial,

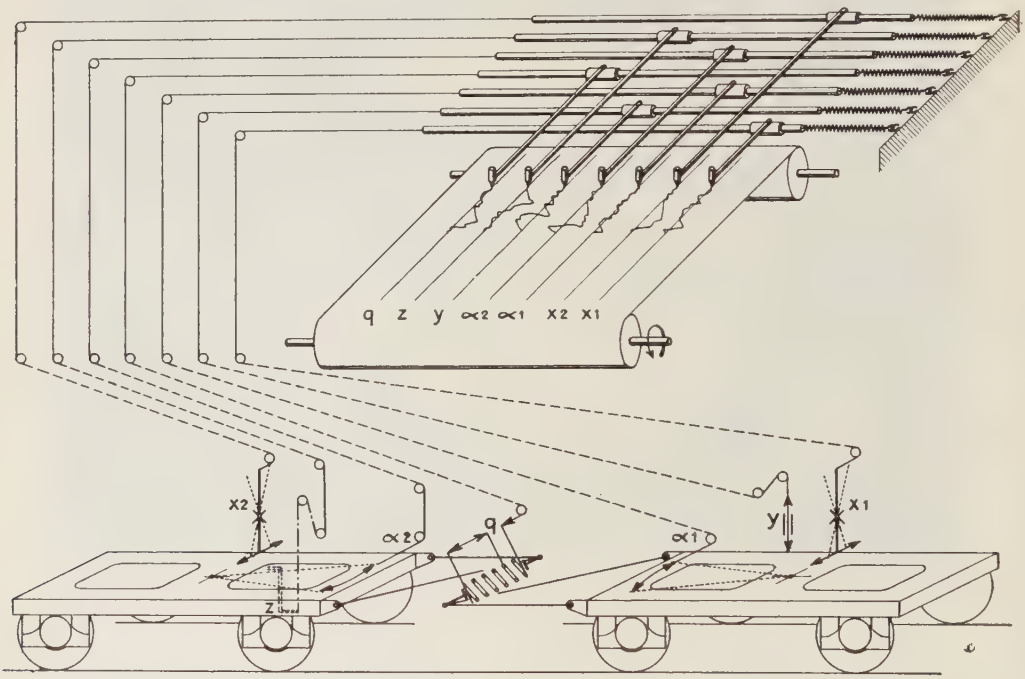

Fig. 5.

the track; play in suspension springs and equalisers; axleboxes, centring devices, bogie displacement, etc. This apparatus records the movements of the points which it is desired to observe, by means of steel cables, without Bowden sheaths, one end of which is attached to these points and the other held by a spring, as shown in fig. 5.

of the results obtained, which will be better than that provided by the diagram alone. In some circumstances these trials have been supplemented by observation of the play between rail and wheel by means of a mirror. As a result of trials of this kind, it has been possible to raise the speed from 90 (56 m.p.h.) to 110 km/h. (68 m.p.h.) or to fix more suitable dimensions for the

suspension parts and universal drawgear of two types of B_0-B_0 locomotives (36. 39).

Trials during recent years with these pieces of equipment confirm the observations made in 1930, according to which the movements of locomotives are caused by the track, and that it is the track which governs the movements. Repeated trials in the same conditions, give results identical in the smallest details; it is therefore necessary to repeat trials only when a diagram is accidentally incomplete. The method of testing in which a vehicle runs constantly and systematically over a short stretch of selected track at various speeds and in various conditions is the best. It permits an assessment of the consequences of modifications in the vehicle.

Trials made with B_0-B_0 locomotives (see (*9*), figs. 18, 19) have led to the following conclusions

1) The anti-hunting device is beneficial on straight track and at speeds of 70-130 km/h. (43-81 m.p.h.). It reduces lateral oscillation of the body by 20-40 %. On curves it has had no noticeable effect.

Fig. 6.

2) The greater the inclination of the suspension links of the body springs, the greater the centring force. A 13° slope of these links reduces the amplitude of the lateral oscillations by 15-30 % compared with a slope of 7°.

3) The friction dampers used are efficient.

4) The lateral play of the transverse coupling has not any great influence on running on the straight; on the other hand, play is necessary on S or small radius curves. On the trials in question, the running of the locomotive was very smooth, but on curves lateral oscillation was very pronounced and the body struck the side checks at high speeds. It was possible to eliminate these shocks by increasing the centring force through a steeper slope of the links.

These trials have been used as a guide for future construction. The good results obtained with the Ae 4/4 BLS and Re 4/4 CFF locomotives have decided several Administrations to adopt this method of construction for their new stock.

Trials to measure rail distortion with which it was hoped to measure the forces exerted have not yet given practical results.

The most delicate point, on which it has not yet been possible to obtain results is the direct measurement of vertical and horizontal forces exercised by the wheel on the rail. At present, the amount of these forces is obtained only by deduction from measurements at spaced points.

It can be reported that certain of the locomotive devices have been established on the basis of laboratory tests made with reduced scale models which have given a guide to the principal phenomena produced in running (*41*) (fig. 33) (*46*) (figs. 57 and 62).

VII.— For future construction, Administrations generally show a tendency to use locomotives with total adhesion. On vehicles which can run at speeds in excess of 120 km/h. (74 m.p.h.), bogies with swing bolsters are preferred. Several locomotives with bogies having three driving axles will have a flexible recoil arrangement acting as a damper, similar to the action of a swing bolster. Bogies without swing bolsters are confined to vehicles, the speed of which does not very much exceed 100 km/h. (62 m.p.h.). Transverse drawgear is general on locomotives.

Several Systems have discontinued the use of axleguards and slides and have substituted joints with silent-bloc fittings or cylindrical studs greased permanently in an oil bath.

According to the region, axleboxes will have plain bearings with mechanical lubrication, or roller bearings.

E. CONCLUSIONS.

I. — The increased speed of trains presents rolling stock builders with difficult problems, particularly as regards the components for transmission of the tractive force to the driving axles and the suspension of driving vehicles. The task of the constructor is to find solutions which reduce to a minimum shocks on the track and give to vehicles an adequate degree of running stability. In general, the most simple arrangements, the operation of which can be easily seen by reason of their clarity, will be the best. Most of the forces coming into play should, from a theoretical standpoint, be compensated by judicious proportioning of the components in construction. However the rolling stock builders meet two obstacles in the observance of this elementary rule, the available space (loading gauge) and the weight (limited by the track). The builder therefore finds himself obliged to use the methods available for compensation to circumvent these two obstacles. He will use supplementary devices such as springs, equalisers, links and dampers which will complicate and increase the cost of construction. It will not be overlooked that each complication raises the risk of unexpected results in particular, account

will be taken of the effects of resonance which may be produced between the various groups of suspension springs, and the drive to the axles, which may give rise to defects. To obtain good results, it is necessary that these should be easily comprehended and maintained.

II. — The present tendency is to use on driving vehicles :

a) nose suspended motors with rigid gears for powers not exceeding 350 HP/axle;

b) nose suspended motors and resilient gears for medium powers of up to 750 HP;

c) fully suspended motors with flexible transmission components to the driving axles for average and high powers up to 1 500 HP/axle.

The three systems of axle drive are used for speeds reaching 150 km/h. (93 m.p.h.).

III. — The increased speed of running demands the use of bogies with supplementary springing between the body and the bogie. On locomotive, transverse drawgear between bogies is tending to become general.

IV. — Most Administrations are proceeding with trials to measure the forces exerted by vehicles on the track and to establish conditions to which the constructional details must conform, with a view to improving running.

It would be beneficial to co-ordinate these investigations.

We cannot conclude this Report without expressing our thanks to the Administrations which have replied to our Questionnaire. We have been greatly helped by the large amount of information which they have supplied at our request and hope that this will in turn have shown them the difficulties in the problems discussed. We must also thank the « Société Suisse pour la Construction de Locomotives et de Machines », Winterthur, and the « Société Isothermos », Paris, for the information which they have so kindly provided.

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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION I.

Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete.

REPORT

(Belgium and Colony, Denmark, France and Colonies, Netherlands and Colonies, Norway, Poland, Switzerland and Syria),

by Léon MARGUERAT,

Chef de la Section des Ponts à la Direction générale des Chemins de fer fédéraux suisses.

PREAMBLE.

This report actually consists of three different reports, all of which however deal with skilled works. The first — « Modern trends in the construction of Railway structures, particulary with regard to bridges » treats the subject quite generally; we have paid particular attention to Railway bridges which form an important chapter by themselves; as regards the remaining categories of work, it was found necessary to restrict ourselves to the consideration of some special points, which appeared to interest the three reporters more particularly, at the time when the general questionnaire was elaborated. The 2nd and 3rd parts deal more particularly with the « Results achieved in the construction of Railway bridges built in ferro-concrete » and the « Future prospects in the employment of pre-stressed concrete », which is the reason why the 1st part only gives a brief summary of these observations. Let us say straight off that it is difficult to give a forecast on the subject of prestressed concrete since experience is lacking; the few ideas put forward cannot do more than state the present position of this method, which may well have unforseeable surprises in store.

These reports submit neither new theories nor descriptions of unusual constructions, for the reporters agreed that there was no point in producing a report which would merely duplicate available technical literature, but that it would be much more interesting to describe the observations, experiments and conclusions recorded by specialists of the various Administrations in order to ascertain « modern trends ». The enquiry, as was pointed out in the preliminary note attached to the questionnaire, ought to be largely an expression of opinion by those responsible for the various structures.

The questionnaires were voluminous and difficult: there were no less than 158 questions, touching subjects which frequently were highly specialised, so much

so that numerous Administrations simply indicated that they had nothing of interest to report. Out of the 48 areas of the group, only 8 have replied to the questionnaire. These are :

The Belgian National Railways Company (S. N. C. B.);
The Danish State Railways;
The French National Railways (S. N. C. F.);
The Tunisian Railways;
The Norwegian State Railways;
The Netherlands Railways;
The Swiss Federal Railways (C. F. F.);
The Emmental - Bergdorf - Thun Railways (Switzerland).

The Algerian Railways and those of Morocco have declared their adhesion to the principles applied by the S. N. C. F. The Dutch Indies State Railways do not consider themselves competent to undertake this enquiry on account of the present political situation. Alone amongst the larger Railways, the Polish State Railways have regrettably made no reply.

* * *

a) Modern trends in the construction (design) of railway structures particularly of bridges.

CHAPTER I.

General remarks.

If the *live loads* which at present serve as bases for calculation of Railway bridges for the principal lines appear at first sight to show some diversity (see plate 1) this is quite superficial. The comparison of « equivalent loads per running metre », i.e. uniformly distributed loads producing, in a single span, the same maximum moment and a comparison of the maximum moments (see plate 3) indicates that the differences are unimportant. France has values about 15 % higher than those of other countries on account of her long locomotives with axle loads of 25 tons.

All the Railways admit that these arrangements will hold good for long periods. It would seem that a ceiling may have been reached. However the Swiss Railways make certain reservations with regard to goods wagons; there is a tendency to build bogies with more than two axles closely spaced up to 1.25 m (49.21 in.), so that the ratio $\frac{P}{a}$ (P = axle load, a = distance between adjacent axles) at times exceeds the theoretical figure. The special groups of 1 × 28 tons, 2 × 27 tons, and 3 × 26 tons, built by the S. N. C. B. form a wise precaution in this respect.

The *coefficient of increase to meet dynamic stresses shows* less unity of view (see plates 2 and 4). This question in fact which has been under investigation for a long time, is highly complex and has never been cleared up; it is at present being examined by several Railways. We shall come back to it later, when reviewing the different types of structures. It is to be noted that the recent re-designing of the new measuring instruments, especially the electric ones having a resistance wire, will now enable the problem to be tackled under more favourable conditions.

The effect of *repeated stresses (fatigue effects)* on metal bridges is taken into consideration by Belgium, Denmark (only when the frequency of the additional loads is high) and by Switzerland in the form of a reduction in the permissible restriction or of an increase in the loading (see table following page).

This effect is ignored everywhere in calculations for reinforced concrete structures. Switzerland, however provides, in its new standards, for stresses reduced by 200 kgr/cm² (2 844 lbs per sq. in.) for the components of Railway bridges as compared to those specified for other structures.

Switzerland — and Norway, which adopts the Swiss rules — take into account the *polyaxial stresses,* basing their calculations on the Huber-van Mises-Hencky theory (constancy of the work of deformation); in the case of the normal ruling (« régime plan ») (normal forces n_x and n_y and tangential force t) a force is calculated σ_g

Belgium	*Denmark*	*Switzerland*
Coefficient of increase of loads in the zones of stress reversal : $K = 1 + 0.4 \frac{A}{B}$	Coefficient of reduction in the zones of stress reversal : $K = 1 - 0.4 \frac{A}{B}$	Permissible stress for Railway bridges : $\sigma = 1.20 \left(1 + 0.3 \frac{A}{B}\right)$ T/cm² A and B any value, provided with their appropriate sign.
A = minimum effort or stress; B = maximum effort or stress.		

known as « the force of comparison » by the formula :

$$\sigma_g = \sqrt{n_x^2 + n_y^2 - n_x \times n_y + 3\, t^2}$$

The stress σ_g must be kept less than the permissible force. A condition of tensile stresses in 3 directions is used in the case of biaxial tensions by neglecting that of the values n_x, n_y or n_z which, in absolute value, is located between the other two. The S. N. C. B. makes use of Mohr's theory. The Danish State Railways maintain that they use the formulae of St. Venant and of Guest, but this is not apparent in the standards of this country. The other systems do not trouble about the polyaxial stresses. Holland uses Huber-Hencky's theory for preventing the permissible pure shear stress; it is sufficient to make $n_y = 0$ and $n_x = 0$ in the above formula in order to arrive at the value $t = 0.58 \times \sigma$.

The S. N. C.B. and Holland have no rules for the *non-isotropic elements (welding seams)*. Norway uses the German standards.

The other systems introduce coefficients which are functions of the nature of the welded seams, their quality, and to the kind of stress these seams must resist; with the help of these coefficients one may either reduce the permissible force in the basic metal (Denmark, France), or change the stress of the welded seam to an imaginary stress (Switzerland). The C.F.F. state that their coefficients represent the ratio of the resistance to the endurance (repeated stresses) of the welded structure to that of the rivetted structure under similar conditions of stress.

The table on the following page reproduces these coefficients.

Taking these coefficients into account, the stresses in the welds should satisfy the conditions shown in the table on page 1661/71.

The French conditions indicate that the effective stresses must remain within the quarters of ellipses of which the demi-axes are respectively $\alpha \times R$ or $\beta \times R$ according to 0_x and $\gamma \times R$ according to 0_y. The Swiss condition is the outcome of the Huber-van-Mises-Hencky theory.

We have shown in plate 5 the envelopes of permissible stresses resulting from these conditions; they refer to mild steel structures, all the overloads as well as wind loading and temperature being taken into consideration, first class welding (France : shop welded; Switzerland : 1st class).

The choice of *the type of work* depends on a certain number of considerations to which we shall have occasion to revert later. Naturally the question of cost plays a big part, both as regards the outlay on construction as well as the maintenance charges. We should note the return to favour of arched masonry bridges and the wide development in the use of reinforced concrete. The aesthetic point of view is

<table>
<tr><th>Country</th><th>Type of weld</th><th>Nature of stress</th><th colspan="6">Values of the coefficients</th></tr>
<tr><td rowspan="5">Denmark</td><td rowspan="3">butt weld</td><td rowspan="3"></td><td colspan="3">Normal stress n</td><td colspan="3">tangential stress t</td></tr>
<tr><td colspan="3">$K_1 = \begin{cases} 1.0 \text{ if buckling is excluded;} \\ 0.8 \text{ with risk of buckling.} \end{cases}$</td><td colspan="3" rowspan="2">$K_2 = 0.65$</td></tr>
<tr><td colspan="3">compression: K_1 as above; tensile: 0.80</td></tr>
<tr><td rowspan="2">fillet weld</td><td>compression</td><td colspan="3" rowspan="2">$K_1 = 0.65$</td><td colspan="3" rowspan="2">$K_2 = 0.65$</td></tr>
<tr><td>tensile</td></tr>
<tr><td rowspan="6">France</td><td rowspan="4">butt weld</td><td rowspan="2"></td><td colspan="3">Welding in the shop</td><td colspan="3">Welding in the yard</td></tr>
<tr><td colspan="2">normal stress n</td><td>tangential stress t</td><td colspan="2">normal stress n</td><td>tangential stress t</td></tr>
<tr><td>compression</td><td colspan="2">$\alpha = 1.00$</td><td rowspan="2">$\gamma = 0.65$</td><td colspan="2">$\alpha = 1.00$</td><td rowspan="2">$\gamma = 0.55$</td></tr>
<tr><td>tensile</td><td colspan="2">$\beta = 1.00$</td><td colspan="2">$\beta = 0.80$</td></tr>
<tr><td rowspan="2">fillet weld</td><td>compression</td><td colspan="3" rowspan="2">$\alpha = \beta = \gamma = 0.65$</td><td colspan="3" rowspan="2">$\alpha = \beta = \gamma = 0.55$</td></tr>
<tr><td>tensile</td></tr>
<tr><td rowspan="7">Switzerland</td><td rowspan="5">butt weld</td><td rowspan="3"></td><td colspan="3">1st class weld</td><td colspan="3">2nd class weld</td></tr>
<tr><td colspan="2">normal stress</td><td rowspan="2">— tan. t</td><td colspan="2">normal stress</td><td rowspan="2">— tan. t</td></tr>
<tr><td>n_x</td><td>n_y</td><td>n_x</td><td>n_y</td></tr>
<tr><td>compression</td><td>$\alpha_x = 1.1$</td><td>$\alpha_y = 1.1$</td><td rowspan="2">$\alpha = 1.1$</td><td>$\alpha_x = 1.0$</td><td>$\alpha_y = 1.0$</td><td rowspan="2">$\alpha = 1.0$</td></tr>
<tr><td>tensile</td><td>1.0</td><td>1.1</td><td>0.7</td><td>0.85</td></tr>
<tr><td rowspan="2">fillet weld(*)</td><td>compression</td><td>0.5</td><td>1.1</td><td rowspan="2">0.85</td><td>0.50</td><td>1.0</td><td rowspan="2">0.70</td></tr>
<tr><td>tensile</td><td>0.4</td><td>1.1</td><td>0.35</td><td>0.85</td></tr>
</table>

(*) In Switzerland the stresses n_x and t are measured at the contact surface between the bead and the parent metal.

Denmark	Butt weld : $n \leqslant K_1 \times R$ and $t \leqslant K_2 \times R$ Fillet weld : $\sqrt{n^2 + t^2} \leqslant K_2 \times R$ For K_1 and K_2 see above table.
France	$t^2 - \frac{\gamma^2}{\alpha\,\beta} (\alpha\, R - n) \times (\beta\, R + n) \leqslant O$ For α, β, γ, see above table.
Switzerland	$\sigma_g = \sqrt{\left(\frac{n_x}{\alpha_x}\right)^2 + \left(\frac{n_y}{\alpha_y}\right)^2 - \frac{n_x . n_y}{\alpha_x . \alpha_y} + 3 \left(\frac{t}{\alpha}\right)^2} \leqslant R$ For α_x, α_y et α, see above table.

R = permissible stress of parent metal in compression or in tension, account being taken of limit stresses if necessary,
n = normal force (n_x, n_y, along the axes x and y).
t = tangential force.

not being neglected; all Administrations are paying attention to this problem, and are giving it an important, even fundamental role (Tunisia); they frequently consult their architectural experts and at times also architects in private practice; artistic beauty is not entirely a dead letter amongst Railway engineers.

* * *

CHAPTER II.

Metal Railway bridges.

a) *Main girders.* — The general tendency points to the simplification of structures. The simple or continuous girder with constant or sometimes varying moment of inertia is preferred (see Figs 1 to 5). Other systems are exceptional and often appear to be dictated by aesthetic reasons; it is thus that the S. N. C. B. constructed Vierendeel bridges having spans up to 112.75 m (370 ft.) (Fig. 6); the Danish State Railways have used the Langer girders in several recent works; Storström (Fig. 8 — span 136.7 m [448.5 ft.]), Oddesund (Fig. 7 — max. span 67.74 m [222 ft.]), Alsund (max. span 74.8 [245 ft.]) and have expressed satisfaction. The S.N.C.F. is at present building a double track bow-string type at Valenciennes for a span of 104 m (341 ft.). The Dutch Railways also report the introduction of some Langer girders (Fig. 9) and two Vierendeel bridges; they state definitely « that bridge girders with flexible booms are not rigid enough especially when it is a question of long span, double track bridges; the secondary tensile stresses in the suspension members are very important and even higher than the primary stresses ».

Denmark has used cantilever girders for long spans (Storström, Little Belt).

The S. N. C. F. and the C. F. F. are in agreement as regards giving up the metal boom in favour of one of reinforced concrete or of a masonry arch. They are retaining the frame (beam with supports) as an interesting solution for bridge decking of light section (S. N. C. F. : up to 30 m

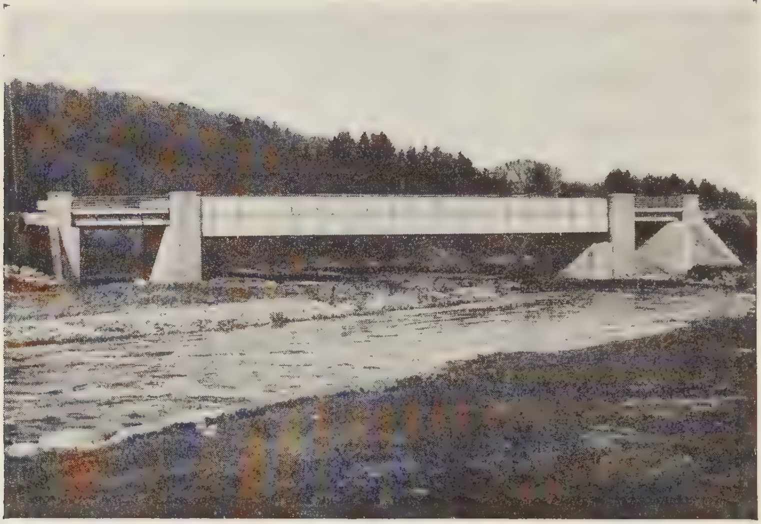

Fig. 1. — *S. N. C. B.* : Railway bridge over the river Ourthe at Melreux-Span : 134 ft.

Fig. 2. — *S. N. C. F.* : Railway bridge at Choisy-le-Roi. — Spans : 152-194-152 ft., 54 steel.

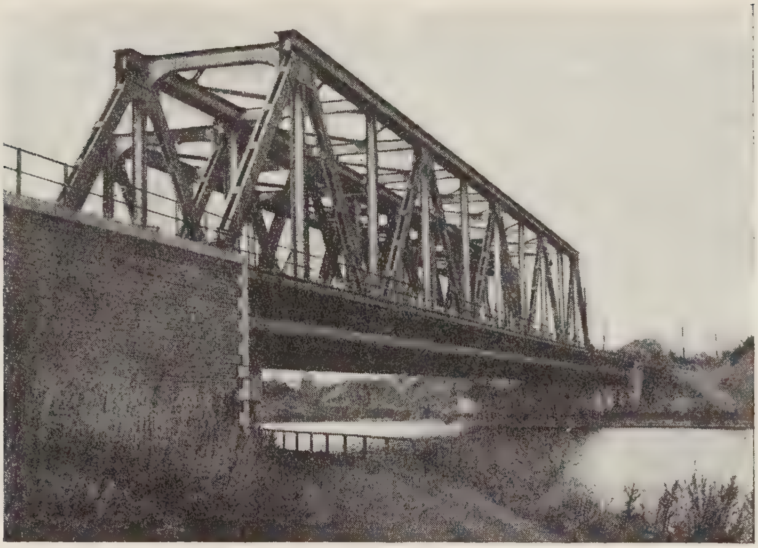

Fig. 3. — *S. N. C. B.* : Railway bridge at Luttre. — Span : 260 ft.

Fig. 4. — *S. N. C. F.* : Eiffel bridge.— Spans : 105 — 315 — 105 ft.

[98.4 ft.] span) and are reserving systems consisting of flexible booms (arched girders) or of truss rods for reinforcements.

The plate girder (Figs. 1 and 2) is gaining ground; it is preferred everywhere, not only for aesthetic reasons, but above all since it is comparatively simple in construction and calls for less maintenance work than the lattice types : concentration of the material in a small number of solid pieces (S. N. C. F.), less marked vibration, no joints.

Below we give the limits of utilisation of the plate girder in Railway bridge construction as practised on the different systems :

Belgium S.N.C.B.	*Denmark* State Railways	*France* S.N.C.F.	*Holland* Netherlands Railways	*Norway*	*Switzerland* C.F.F.
Economical up to $\sim$ 36 m Works carried out up to $\sim$ 41 m	Storström cantilever bridge. Max. span 57.78 m	Simple girders : L $\sim$ 35 m h = 3.50 to 4.00 m continuous girder (actually built) 59.20 m Increase of weight allowed over the lattice girder 10 to 15 %.	Span $\sim$ 25 m (prewar)	Span : $\sim$ 30 m Height : $\sim$ 3 m	Single track Simple girders: rivetted : 40 m; welded : 35 m Continuous girders: rivetted : 60 m; welded : 50 m

Fig 5. — *Danish State Railways :* Little-Belt bridge.

Fig. 6. — *S. N. C. B.* Gellick bridge over the Albert Canal. — Span : 370 ft.

Fig. 7. — *Danish State Railways :* Bridge over the Strait of Oddesund.

As regards *lattice girders* (Figs. 3 and 5), preference is almost always given to the simple trellis (minimum secondary stresses), particularly to the V type which has an having a low level track « where the skew does not allow a correct design of panels in simple trellis construction ». The S. N. C. B. are at present building girders

Fig. 8. — *Danish State Railways :* Storström bridge. — Span : up to 448 ft.

especially attractive appearance. The Tunisian Railways always prefer the double trellis type. The S. N. C. F. consider the quadruple trellis girder advantageous for large span bridges with a raised track; they also employ this type for large skew bridges of diamond pattern, as an experiment and also on account of their attractive appearance (see Fig. 10).

Qualities of steel. — All the systems as a rule use mild steel quality Ac. 37 to Ac. 44, at 24 kg/mm^2 (34 136 lbs per sq. in.)

Fig. 9. — *Netherlands State Railways :* Zwolle bridge

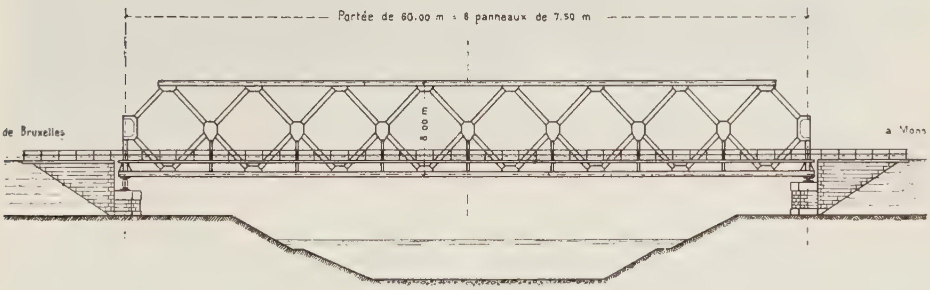

Fig. 10. — *S. N. C. B. :* Nimy-Maisières bridge. — Lozenge beam.

elastic limit, 20-24 % elongation. The middling hard steels Ac. 54, are reserved for certain work of wide application subject to fairly high stresses. The S. N. C. F. who refer to several applications of this steel (see Fig. 2) stipulate an application, pending further instructions, limited to plate girders « on account of certain difficulties in rivetting ». Denmark has used « Cromador » steel (R = 58 kg/mm² [8 245 lbs per sq. in.]) for the Storström bridge and Krupp 52 for that of the Little Belt.

The Swiss Federal Railways consider the resistance and endurance (under repeated stresses) of the special steels is relatively

poor, and this has caused them to lose interest in them to a considerable extent.

On the other hand, the Tunisian Railways now make regular use of the medium hard steel Ac. 54, the cost of transport on 2 000 km (1 240 miles) being of importance to them; this quality of steel moreover is less subject to rusting. The same Company has used copper-steel alloy and pure soft iron in places where conditions are particularly favourable to oxidation and they state that they are satisfied with the results.

Light alloys have not yet been utilised, on account of their high cost, their ready deformability, and lack of durability; they cannot be considered except for portable bridges, for the colonies, or on mountain Railways, and also for certain accessory components (i.e. footbridges for the staff).

There are so far not many *welded Railway bridges.* As regards *plate girders,* the S. N. C. F., Norway and C. F. F. report a certain number of applications, Denmark only one instance; the S. N. C. B. states that they have at the moment only confirmed one case in which welded steel has given satisfaction (Fig. 12). The Dutch have made a few trials (box girders of 26.8 m [88 ft.], height 1.25 m [4.1 ft.]), sole plate up to 48 mm [1.889 in.]); they have had disappointments; cracks have appeared in the webs of the girders, around the ends of the distance pieces; there also occurred severe deformation: moreover the Dutch no longer weld up plate girders for Railway bridges. The S. N. C. F. allow their designers freedom in supplying different methods of welding; they permit welding on the job subject to a reduction of the stresses allowable; they employ all the R. S. sections (1/2 DIN, flats, etc.)

Fig. 11. — *Norwegian State Railways :* Welded railway bridge.

limiting the thickness of the first sole plate to 25 mm (0.984 in.) in the case of flat iron. Actual practice in France however does not go beyond beams of about 1.5 m (4.9 ft.) in height (one exception is for 2.3 m [7.55 ft.]) the designers themselves reserving this point. The Norwegian Railways permit welding for spans up to about 20 m (66 ft.). They report 19 spans of 3 × 36 m (3 × 118 ft.): another is being studied with continuous spans of up to 48 m (157 ft.). The C. F. F. prefer the framework to be in single flat plates of varying thickness (max. 50 mm [1.97 in.]).

None of the bridges in service in France, Norway and Switzerland have, up to now, given cause for any criticism due to the fact that the work has been welded.

Fig. 12. — *S. N. C. B.* Bridge with welded struts. — Span : 59 ft.

entirely welded, in steel 37, up to 17 m (56 ft.) span (Fig. 11); all the welds were made in the shop; the sole plates are special plates from Dortmund (grooved) of 32 mm (1.26 in.) thickness maximum; the Norwegians say they are satisfied, but they think that the Domnarvet (Swedish) section with tongue is still better since « it produces a beam of monolithic character and makes control by X-and Y-rays possible. » The C. F. F. only welded No. 37 steel (exceptionally No. 44), and they do not allow welding during erection. The longest span they have welded so far is 26 m (85.3 ft.), with 2.8 m (9.2 ft.) height of beam, but they are putting in hand a continuous job

The *welded lattice girder* is much less common. In fact there is only one Railway bridge of the lattice girder type that is entirely welded on all the Railways with which we are concerned : this is the well known bridge of Joncherolles (S.N.C.F.) near Paris (span 39.86 m [131 ft.], skew angle 32° 36′; lattice in V without verticals, lower frame work in flat plates) described in the *Technique des Travaux* of July 1939. This bridge is behaving satisfactorily. The solution of the problem consisting in reducing the height of the bars in order to reduce the secondary stresses, appears to be a very happy one. The C. F. F. have had trouble already in the shops with a V

girder of 37.3 m (122 ft.) span (Fig. 13) so serious that ultimately the joints had to be rivetted. The Dutch had built a bridge for a 56 m (184 ft.) span in 1940-41, with the bars welded, and the connecting attachments rivetted. It was destroyed during the war. Reconstruction included the use of welded tubular elements, but these had to be given up on account of internal tensile stresses.

the system satisfactory up to 30 m (98 ft.) span. The C. F. F. refer among others to a continuous bridge of 2×20 m (2×66 ft.) (Fig. 15) and to the early completion of another beam of 3×36 m (3×118 ft.) where the tensile stresses in line with the piers will be reduced by lowering the level of the supports. The other Railways have nothing of this description to show as yet.

The ticklish point remains at the junction between beam and concrete. The S. N. C. F. favours round iron bars, welded, while the C. F. F. use welded angle pieces, worked into I-shaped joists, as small and close up as possible. The effect of shrinkage is not well defined; the C. F. F. are thinking of making experimental tests. In any case the concrete must be of high quality, minimum shrinkage, and it is inadvisable to concrete more than 5 to 6 m (16 to 20 ft.) at a time. The S. N. C. F. is doubtful of the permanence of the security of the joints and indicates « certain action

Fig. 13. — *Swiss Federal Railways :* Trellis railway bridge with welded trellis and rivetted points. — Span : 122 ft.

The « *combination* » *beam* or *mixed steel and concrete girder*, in which the covering of reinforced concrete takes a share in the strength of the girder, is no longer in its infancy in France; the S.N.C.F. mention numerous examples, among which are 2 continuous beams with a raised track, the one of 3×25 m (3×82 ft.) (Fig. 14) and the other 2×35 m (2×114 ft.); in order to make the concrete share equally in the stresses in the region of the supports, these are cut down so as to suppress the tractive stresses. The S. N. C. F. consider

which seems to point to a variation in the time that the deck plating in ferro-concrete requires for setting ».

On *double track lines,* France, Holland and Switzerland prefer the decking separated at double track bridges, which facilitates maintenance and at times may allow a reduction in the height of construction. Denmark points out that this depends on the span. The S.N.C.B. chooses the double track bridge on account of its economy.

The use of *supports on roller bearings* is obligatory for spans in excess of the following figures :

Belgium	*Denmark*	*France*	*Holland*	*Norway*	*Switzerland*	*Tunisia*
18 m	12 m	15 m	20 m	16 m	10 m	15 m

The S. N. C. F. are at present experimenting with a view to reducing the weight of supports. Judging by the examples quoted, this should be a matter of considerable interest :

— apparatus with 1 roller, load 320 t; weight 650 kg (1 433 lbs);

— apparatus with 1 roller, load 87.5 t; weight 100 kg (220 lbs).

In order to allow for *expansion of rails* at the ends of the metal bridges, Denmark, France, Holland, Norway and Switzerland make use of very similar arrangements, « points blade » (lame d'aiguilles) (Fig. 18) for spans exceeding the following values :

Denmark	*France*	*Holland*	*Norway*	*Switzerland*
55 m	50 m	type 1: 30 to 60 m type 2: 60 m	100 m	80 m

This apparatus is generally placed outside the deck. The Dutch and Norwegian Railways also place it in line with the intermediate joints of the large bridges.

b) *Covering.* — In the case of *bridges with decks completely of metal* the track is generally laid on sleepers, a system which guarantees keeping the correct gauge, more surely than laying the rails on longitudinal sleepers and also allows of fixing anti-derailment arrangements. The S. N. C. F. however prefers the use of longitudinal sleepers for works that are in alignment; the amount of wood used is smaller (75 %) and the dynamic effects are reduced. The Tunisian Railways prefer the two solutions mentioned and have recourse to metal chairs having a height of 10 cm (3.9 in.) (see Fig. 16) rivetted to the stringers, with rubber packing pieces between the rails and the tie plates. This arrangement allows for a gain in height.

Continuous longerons placed above the tie bars are rarely adopted, in fact the method is going out of use altogether. Entirely metallic decking is only of particular interest when the clearance in height is small; in this case one has to box the longitudinal sleeper into the tie

Fig. 14. — *S. N. C. F.* : Railway bridge at Theux, mixed steel and concrete construction, continuous girder. — Span : 3 × 82 ft.

Fig. 15. — *Swiss Federal Railways* : Railway bridge Bärschwil, mixed steel and concrete construction, continuous L-type girder = 2 × 66 ft.

bars. The different Railways are of one mind here : the longitudinal attached to the tie bar without a chair to secure continuity is unsatisfactory; the rivets lose hold. The C. F. F. even report cracks in the body of the longitudinals at their extremities. Plates 6 to 9 show examples of satisfactory attachments. The Dutch have brought out a fishplate to attach to the lower wing of the longitudinals, see their most recent construction; the C. F. F. propose to introduce this when the elasticity of the system produces positive moments.

The S. N. C. F. sanctions the welding of longerons with tie bars and tie bars with main girders (see Plate 10) « while taking the usual precautions to obviate the troubles due to shrinkage ». The Swiss only partially weld these combinations, in order to allow for a certain flexibility (see Plate 11). The remaining Administrations do not weld.

We add to plate 12 some of the solutions applied to the problem of the butt jointing of metallic decking. The principle is everywhere the same; a cross bar at the extreme end rests on an extension of the longerons. In the case of a slightly oblique Railway crossing, the structure is built like a straight bridge; but if the oblique angle is pronounced, these extensions are no longer brackets but are beams supported specially on the abutments and designed so as to take up the difference due to the oblique angle.

The attitude of the Administrations on the subject of *arrangements to prevent derailments on bridges with complete metallic deckings* is summarised below :

Belgium	*Denmark*	*France*	*Holland*	*Norway*	*Switzerland*	*Tunisia*
Guard rails on bridges of large span and great height, having track raised to considerable height.	Guard rails on important bridges.	Bridge deck — track arranged so as to restrict the effects of a derailment. No other devices.	⊥ type beams on cast iron chairs.	Guard rails on bridges exceeding 10 m span.	Guard rails on bridges exceeding 20 m span.	On certain bridges ⊔ - type check rails fixed to the deck plating.

The Dutch Railways and the C. F. F. have had the opportunity to verify the efficiency of their arrangements.

The advantages of a *covering of reinforced concrete on metal bridges* are emphasized by Denmark, France, Switzerland and Tunisia, who adopt this system « whenever it is practicable » (S. N. C. F.) or « reasonably possible » (C. F. F.). These advantages are essentially the following :

continuity of the deck, whence easier running of the vehicles and readier maintenance of the track; diminution of vibration and of fatigue effects due to increase of dead loads; suppression of the fastenings of sleepers (or of longitudinal sleepers) and of stringers; simplification in laying the track when it is on a curve, and likewise in linking up the latter with the regular track. The increased cost due to the extra weight of the plate girders is generally compensated by the economy gained in the decking.

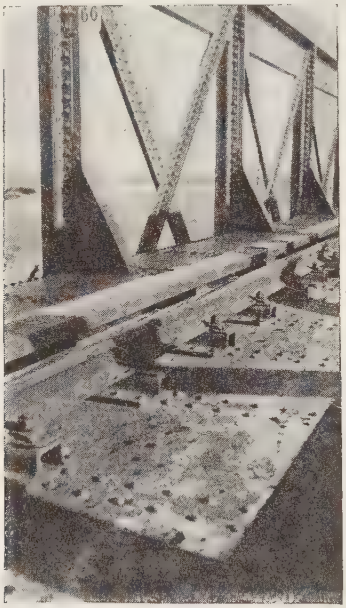

Fig. 16. — *Tunisian Railways :* Sole plates for fixing rails on metal bridges.

The S. N. C. B. appreciates the continuity of the deck platform, but fears « the difficulties of securing watertightness of the proposed construction », hence they do not use reinforced concrete coverings for metal bridges, but they use plating of pressed or dished plates galvanised or machined. The Dutch think that concrete decking is apt to lead to bridges of excessive weight and to designs of undue height.

The connections between the concrete decking and the girders are shown on plate 13 for bridges carrying the track at low level; here it will be useful to separate the deck from the girders if the width of the bridge allows it; the problem of the connections will then be simplified. When on the other hand bridges have tracks placed at high level, the flooring rests on the framework and it is nearly always preferable to make sure of the bonding of the two elements and thus to realise the « combination » system. The Tunisian Railway Company are however not of this opinion. They have experienced defective joints in their mixed concrete and steel structures, due to the parting of the steel and concrete surfaces by rust and corrosion forming on the face of the steel. Hence

Fig. 17. — *Tunisian Railways :* Prefabricated concrete decking for metal bridges.

they use prefabricated contiguous floor plates of 20 to 25 cm (7.9 to 9.8 in.) width set on metal girders with 4 mm (0.16 in.) lead plates sandwiched in between the latter and the aforesaid floor plates. This system appears to give complete satisfaction (see Fig. 17).

The following conditions are moreover foreseen for this type of deck :

	Denmark	*France*	*Switzerland*	*Tunisia*
Ballast	Min. 25 cm under the sleeper	Min. 25 cm under the sleeper	Min. 40 cm of which the bottom layer is 10 cm: 10—20 mm	30 to 40 cm of which the bottom layer is 10 cm: 5—25 mm
Capping	5 mm of bituminous jute. Cement mortar 40 mm	The S. N. C. F. aims at a watertight support. The efficacity of cappings strikes them as doubtful.	10 mm bituminous jute. Cement mortar 40 mm	No capping. The water is drained away through the joints in the floor plates.
Arrangements for preventing derailment.	Check rails on important bridges (Storström)	Nil.	Check rails on bridges of more than 20 m on a curved track and for important bridges.	Nil.

The special bottom layer of ballast is laid with the essential object of preventing the prevailing coarser elements of the standard ballast, which has sharp edges, from damaging the capping.

Amongst the Administrations concerned, the S. N. C. F. alone has tried *laying the track on a covering of reinforced concrete without any ballast.* This is laid over sleepers, over longitudinal sleepers or on metal packing plates, but in every case through the interposition of rubber plates. The S. N. C. F. refers to this matter as follows :

« The difficulty lies chiefly in obtaining ready and exact adjustment of the track when it is being laid.

» We are continuing the experiments on laying track direct (sleepers or packing plates) since we consider that this solution is rich in future possibilities (advantages of the ferro-concrete deck plating in regard to maintenance cost — notable reduction in thickness and weight as compared with bridge ballasting).

» In view of this method of laying the track, we do not provide special arrangements to prevent derailments. »

The Tunisian Railways have had trouble at level crossings where the rail is fixed directly on bearers of reinforced concrete; the rail has gradually sunk into the concrete.

This very complex problem of *dynamic effects* (see plates 2 and 4) in metal bridges has not been solved. Although the different Railways admit that they are in general more or less satisfied with their formulae, nevertheless none of them take into account either the speed of the trains

Fig. 18. — *Danish State Railways :* Check rail and expansion joint.

Fig. 19. — *Netherlands Railways :* Check rail in Z bearers.

nor the state of the track. The French formula alone introduces the weight of the unit of transport and the overload to which it is subjected; all the others depend solely upon the length of the unit or on that of the part subjected to load. The influence of the rail joints is not yet determined. Thus the S. N. C. F. « has not noted any difference between the sag in a joint where the play has been neutral-

Fig. 20. — *S. N. C. F. :* Montlouis masonry viaduct over the Loire. 14 elliptical arches of 81 ft. span.

Fig. 21. — *S. N. C. F. :* St. Côme viaduct over the Loire, 15 basket handle arches of 79 ft. span.

Fig. 22. — *S. N. C. F. :* Maurépire viaduct; 8 arches of 43 ft. span.

Fig. 23. — *S. N. C. B. :* Roanne-Coo viaduct, 8-41 ft. straight arches and 2 — 82 ft. skew arches.

Fig. 24. — *C. F. F. :* Junction bridge at Geneva. Flattened segmental arches with spans of 187 — 172 — 151 ft.

Fig. 25. — *Swiss Federal Railways :* Zweidlen viaduct, 8 arches — max. span : 64 ft.

ised at the centre of the span and with the same joint open as much as 12 mm (0.472 in.). This applies to different bridges of from 15 to 40 m (49 to 131 ft.) span. However several countries (Belgium, Denmark, Holland and Switzerland) take rail joints into account in their formulae, and all the Railways, save Norway, systematically suppress these joints on bridges entirely of metal; on the other hand the C. F. F. and the Danish Railways weld the rails on bridges with reinforced concrete deck plating.

Here we have a very interesting field for research. The S. N. C. F. and the C. F. F. intend to make systematic tests with a view to elucidating the question.

* * *

CHAPTER III.

Arched masonry bridges in concrete or stone.

Arched bridges are undoubtedly in favour in countries such as France and Switzerland where the soil is particularly favourable. The S. N. C. F. do not hesitate to place them at the head of the list, i.e. « they will build an arched bridge wherever local conditions permit ». The Swiss Federal Railways share this opinion to a large extent; they are now building arched works wherever this is possible, even if, exceptionally, the cost is slightly higher (5-10 %) than that of other systems ». The position is different in flat countries or where the subsoil provides a difficult foundation; hence Belgium is less enthusiastic in this respect; Denmark and Tunisia only adopt the system exceptionally; Holland rejects it entirely considering that reinforced concrete is lighter and more economical. Norway has had no opportunity to build large arches in the last 25 years.

Figures 20 to 25 show some recent works carried out. The S. N. C. F. following the destructions of 1940-44 announce a whole collection of magnificent works; the bridge over the Rance at Lessart at present under

Fig. 26. — *Swiss Federal Railways :* Proposed reconstruction of the bridge at Kerstelenbach; arch : 256 ft.

construction will have an arch of 88 m (288′ 8 5/8″) opening; the arch will be depressed by 1/3. The C. F. F. also mention several new works and reconstructions shortly of 14 bridges of 21 to 78 m (68′ 10 3/4″ to 255′ 11″) opening.

The advantages of masonry bridges are well known; cost is comparable with that of other types of bridges, often even lower; maintenance cost is very low provided the construction is correctly carried out; practically unaffected by dynamic action and by increase in overloads.

The *choice between concrete and stone* is principally a question of price; in certain cases it may be dictated by local conditions, especially when it is a question of reconstructions. Denmark builds only arches in concrete; Norway does the same with a few exceptions. France, Switzerland and Tunisia would prefer to build entirely in stone, which has a better appearance and withstands the weather better; however for reasons of economy, the S. N. C. F. and C. F. F. frequently adopt the mixed type (concrete covered by rubble) to which the S. N. C. B. also has recourse; this conciliates the questions of the cost, the aspect and protection against the weather; on the other hand contraction is more pronounced than in stonework, and means must be adopted to remedy this : contraction joints, concreting the voussoirs, regulation of the line of pressure by screw jacks in the case of large arches. The coating with rubble is generally limited to *exposed faces;* the soffit is more often visible in concrete. The junction between concrete and stone is always satisfactory if care is taken to alternate the lengths of the shanks of rubble; the S. N. C. F. recommends « pushing forward alternate rubble stones with very long shanks »; the S. N. C. B. complete their liaison by metal anchorages. No system reports any difficulty due to the difference in the modulus of elasticity of the two materials; in the view of the C. F. F. the risk is not great; since E in masonry is smaller than in the case of concrete, there cannot be concentrated stresses on the facing of stone. The danger arising from the difference in contraction appears to be more real, although no defect is reported due to this fact. The Tunisian Railway Company however forbids the mixed type on account of these contraction phenomena. The dressings seen of the works in concrete are everywhere treated with great simplicity :

S. N. C. B.	*S. N. C. F.*	*Norway*	*C. F. F. Switzerland*
Soffit : metal shuttering. Crests of the arches : roughening.	Shuttering well finished. — Roughening with the heavy mell or splitting off by chisel. — Exceptionally : incorporated dressing, 6-8 cm of stone cement or white cement.	Generally speaking no treatment. — Occasionally painting. —	Shuttering well finished. — Coating incorporated. — Exceptionally : roughened surface of stone or imitation stone.

The masonry of the *artificial voussoirs* has only been used exceptionally by the S. N. C. F. (impossibility of obtaining rapidly the necessary natural stone for partial replacements) and by the C. F. F. The process does not seem to be of particular interest. The S. N. C. F. prefers the obvious concrete if the natural stone is too costly. The C. F. F. do not have recourse to it « unless the materials are specified to be of unusual regularity ».

Some of the rules practised on the different Railways are summarised below :

	Belgium S.N.C.B.	*France* S.N.C.F.	*Norway*	*Switzerland* C.F.F.
Dimensions	Typical designs for arches of different surbasements from 4 to 20 m of opening. Beyond this calculations are based on strength of materials.	Thicknesses according to « Séjourné » formulae up to 30 m opening; verification that the pressure curve lies in the central third. Typical designs for PI up to 30 m.	Typical designs for short openings. Large arches calculated by the theory of elasticity.	Thickness according « Séjourné » formulae up to 15 m opening; verification of the line of pressures from about 10-15 m. Beyond 15 m theory of elasticity.
Articulations	Articulated arches very rare. (Metallic articulations).	Never any articulations. Localisation of cracks by arranging for a joint on the extrados at the start of the fissure and on the intrados at the crown.	Occasionally metal articulations.	Only two bridges effectively articulated (arches flattened in doubtful subsoil; 3 metallic articulations).
Building in layers	Never done.	From openings of a few metres arranged with 2 or 3 rollers. Given a solid footing by means of interdependent redans and anchoring bars.	For large arches.	Important arches ($\sim > 40$ m). Solid footing by means of interdependent redans and anchoring bars.

The Danish Railways use Bartel's formulae for dimensions of arches up to 8 m opening; beyond this figure they always provide for arches with three metallic articulations. The Tunisian Railways report several arches with fissures due to the fact that the thrust determined graphically but with insufficient precision (Méry) really was outside the central third of the foundations.

The C. F. F. have had opportunity to compare the values given by the formulae of « Séjourné » with the results of more precise calculations. They have confirmed that the value to be given to α in these formulae, oscillates between 0.16 and 0.17 for Railway bridges; the width at the start is equal to 1.7 - 1.9 times that at the crown.

The *modulus of elasticity* of works in masonry of stone is not very clearly known. It would be good to carry out a series of systematic trials. The C. F. F. made in 1948 some measurements on a relieved arch of 36.74 m theoretical span and 11 m rise of the main arch; firstly under concentrated load of 40 t at the crown of the large arch still isolated, i.e. before construction of relieving arches, then followed by the regulation test of the finished work. The modulus of elasticity corresponding to these cases of loading amounted to from 100 to 120 t/cm².

The S. N. C. F. realised considerable economies on the centres by *building the arches in several layers.* In this way the company was able to « utilise on a large

scale centres made up of rails, even for elliptic arches of 30 m (98′ 5 1/8″) opening ». The same authority is at present carrying out researches to determine the effect of contraction on the different layers of concrete during execution of the work.

The *contraction* in masonry arches of stone is in general neglected. The *extrusion* (fluage) is only taken into consideration for very large arches; its action is compensated for at the same time as that for contraction by regulating the line of pressure, by means of jacks or by means of provisional articulations.

The limit span above which it is of no interest to *relieve the arches* by making them semi-circular, is put approximately at 15 m (49′ 2 1/2″) by the S. N. C. F., at 20 m (65′ 7 3/8″) by the S. N. C. B. and C. F. F.; these values would be higher for flattened arches.

The characteristics of the *concretes* used in work on arches are shown in plate 14. The gauging in cement is from 250 to 300 kg/m^3 of concrete used; the thickness of the aggregates runs normally to 60 mm (2 23/64″). The stresses in small and medium work ($<\sim$ 30 m) remain reasonably moderate, above all it is sought to obtain a good compact concrete, watertight. In larger works, it becomes necessary to combine equally compactness with mechanical strength; a special granulometric test or study is then called for. Vibration by means of pervibrators is almost universally employed.

As regards the *masonry used in stone bridges*, only the S. N. C. F. and C. F. F. have supplied a nomenclature for the various rubbles and stones as well as a scheme for their utilisation; these we reproduce in plates 15 to 17. *France* distinguishes between various qualities of stone : semi-firm, firm, hard and cold, according to their resistance to crushing; the choice depends on the importance of the work. The stones of one quality or another are delivered by the quarries under the descriptive terms of hewn stone, small stones squared off, and rubble stones (squared off, split up, sawn, cleaving the stone, lie of the stone or crude) which characterizes the type of masonry. The tendency on the S. N. C. F. is « to leave to the supplier, according to the depth of the bed and the length of the stones, the greatest amount of liberty consistent with an acceptable scheme of architecture ». This is done « in order on the one hand to reduce the cost of specialised labour and on the other to allow of the greatest possible utilisation of the stones taken from the quarries ». All the heavy jobs of filling in, etc., are done with crude rubbles; the pedestals of medium and small works are done with rubbles sawn or cloven, with a very rough rectangular or trapezoidal face, and with any aspect; the squared rubble is reserved for the stringers of arches, in the same way with pedestals and faces of piles in important works. The use of cut stone is exceptional (see Plate 15).

The Swiss distinguish between crude rubbles (hammered for trimming), drilled or scappelled and cut stone. The length of rubble stones bedded down is 1.5 to 2.5 times their depth; in rare cases 3 times. In Switzerland too there is a tendency to simplify the tools; much use is made of crude or hammered rubble; the dressed or scappeled stone is reserved for string courses, sometimes for soffits; the use of cut stone is rare. We should note however that type of masonry may be dictated by the stresses, hence by the importance and the character of the work (see Plate 17).

Two opposing tendencies are to be noted in regard to *filling materials* between the tympanum and supporting wall. Belgium, France and Tunisia use assorted dry stone, since concrete, so says the S. N. C. F. « by uniting with the material of the arch, modifies the conditions of resistance ». Denmark, Norway and Switzerland prefer poor concrete in order to avoid any thrust against the tympanum walls.

The C. F. F. have confirmed that the best

filling in dry stone ends up by deteriorating, either that the stone crumbles, or that in course of time the interstices fill up with powdery material which produces stresses; the presence of dry stone further complicates the ultimate maintenance of the capping or copings. The argument remains undecided.

Below is given a résumé of the *arrangements for watertightness* :

	Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Norway*	*Switzerland* C.F.F.	*Tunisia*
Nature of material	Asphalt 20 mm — Protection by mortar 40 mm	Impregnated jute 5 mm — Protection by cement reinforced by iron wire : 40 mm.	Mortar capping of 20-30 mm and arrangement of reinforced concrete to the right hand of the joint for capping.	2 layers of tarred felt. Protection for cement 30 mm reinforced by wire netting.	Impregnated jute in 2 layers = 10 mm. — Protection for cement reinforced by wire netting 40 mm.	Cement coating on wire netting : 30 mm. — 2 layers coal tar or bituminous products. — Protection by lime mortar 50 mm.
Place	On the extrados	On the concrete filling.	On the extrados.	On the concrete filling.	On the concrete filling.	On the extrados.
Minimum slope	2 %	—	—	2 %	2.5 %	—

The S. N. C. F. confirms that the « flexible » or asphalt cappings break in line with the fissures in the arches; for this reason they prefer the arrangement of return flow of water above the joints at the starting point of the fissures (see Plate 18). Putting aside the case of single arches, where water can generally be returned to the rear of the abutments, pipes to discharge the water are provided through the arches. The minimum diameter of the pipes is 8 cm (3 5/32″) in Tunisia, 10 cm (3 15/16″) in Norway, 15 cm (5 29/32″) in Switzerland and 20 cm (7 7/8″) in Belgium. The C. F. F. strongly advise straight and vertical pipes. The S. N. C. F. use flows in the shape of a truncated cone of 8 to 15 cm, widening towards the outside (see Plate 18); straight pipes are supplied with a very rapid fall, easily kept clean; the « principle being to discharge the water as rapidly as possible ». The Tunisian Company insists on the fact that these discharges must be inspected frequently. Only the Swiss have had trouble with frost : a plug of ice sometimes forms at the opening of the pipes, which are more exposed to cold than the interior

of the arrangement and the channel through the bridge is apt to fill up with water. Hence it has been necessary to instal electric heating apparatus in places for thawing the drains. The C. F. F. in specially cold districts, revert to drains of very large diameter (40 cm = 1′ 3 3/4″) at the interior of the piers. All the Railways reject drainage across the arches since this method soils the masonry.

Hitherto the S. N. C. F. alone has made use of *expanding cement*, especially for repairing partly damaged arches; its use on new work has been limited, since its application is a somewhat tricky job and its behaviour in the lapse of time is still not well known.

Norway and the C. F. F. supply *check rails on arched bridges*, the first named starting at 10 m (32′ 9 3/4″) span and the second only where the bridges are built with a curvature of less than 500 m (1 640′ 5″) radius and where their length exceeds 50 m (164′ 1/2″). A derailment enabled the C. F. F. on one occasion to verify the advisability of this provision. The S. N. C. F. designs the crowns of the arches in such a way as to limit the consequences of a possible derailment.

When the design of a double track bridge calls for its execution *in two stages*, the two halves are separated by a longitudinal joint, in order to avoid the differences in contraction and flow of material and to protect the part under construction from the effects of deformation and vibration of the part already in service. In plate 18, we show the Belgian and Swiss methods of making this joint. The C. F. F. advise that they have abandoned joint covers in sheet metal fixed to the two halves of the bridge, since they do not stand up to the effects of fatigue, even if they are made flexible.

For the *dynamic effects*, we refer to plate 2. Only the S. N. C. B. ignore these effects in arched bridges. The Tunisian system which adopts the French formula, introduces « the dead weight of the part lying above a horizontal plane passing through an average third of the arch ». The Swiss C. F. F. have made some observations of the rise of arches; they have found a coefficient of 1.25 for spans of ~ 10 m (32′ 9 3/8″) and 1.15 for those of ~ 45 m (147′ 7 3/4″). It would be interesting to multiply these observations on the basis of the existing stresses. It would appear that the dynamic effects should not be neglected in connection with arched bridges.

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CHAPTER IV.

Reinforced concrete Railway bridges.

Such bridges are dealt with separately in part *b*); prestressed concrete Railway bridges are mentioned in part *c*).

* * *

CHAPTER V.

Railway bridges with girders encased in concrete.

Such bridges enjoyed almost universal popularity until shortly before the last war, i.e. as long as the small girders or beams were cheap. The advantages of the system are considerable : simplicity in manufacture, facility and rapidity in erection, minimum height of construction; by suspending the shuttering from the small beams, free passage is secured below the work.

On the other hand, this system calls for a large amount of iron, which is very costly for the majority of systems. If this disadvantage is not great for Belgium, a major producer of iron, the S. N. C. F. is less sure of the matter and classes this type of bridge third in order, i.e. before those with metal decking but after bridges in reinforced concrete. Denmark, Holland and Switzerland only follow this order when the advantages quoted favourably affect the question of cost; as to Tunisia, for whom the cost is much higher on acount of heavy freights, they consider that the « embedded slab has had its day ».

Norway states that this type of construc-

tion is expensive and not very satisfactory.

The cost is indeed not the only defect in this case. Many systems note the damage due to condensation water, when the lower flange of the light girders is not embedded in concrete; the girders forming the edges suffer particularly from the defective jointing of the protecting covers; contraction may damage the adhesion between concrete and iron, especially when the beams are rather high. It becomes necessary to provide transverse stiffeners in order to prevent deformation and we must not forget that the concrete, although it may generally be considered as a simple filling, forms part of the beams, of which it embodies the deformations; we must therefore reinforce it, otherwise it will tend to crack.

It is nonetheless true that the beams embedded in concrete are an example of a classic procedure; the proof of this is the fact that many systems have laid down typical designs. The maximum spans achieved so far were carried out by the S. N. C. F. : bridge of 26 m span at the Villeneuve-Marshalling yard, one span, with 58° of skew angle; bridge with five spans of 28.50 m at Thionville.

Below we give a résumé for the limits of utilisation proposed for the reinforced platforms with plain filling or with reinforcing ribs :

	Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzer-land* C.F.F.	*Tunisia*
Full slab	10 m	simple ~ 13 m continuous 17.50 m	23 m	light iron joists ⩽ 45 cm	10 m	simple : 20 m exception-nally 22 m	Reinforced concrete more advan-tageous alrea-dy for 8 m
Ribbed slab	20 m	nil	—	light iron joists > 45 cm	nil	nil	nil

The hypothesis generally admitted for the *calculation* is that the iron is alone in determining the strength of the deck. One does not realise as a rule that only a slight economy is gained by introducing the concrete, and that this economy is neutralised by the auxiliary devices intended to ensure that the two materials will mutually support each other; it is hardly worth while except for the sake of increasing the span or gaining a few centimetres on the height of the structure (with an equal number of small beams, the support obtained by the concrete in general allows for the adoption of the next lower section of large flanges). Nevertheless the « Compagnie Fermière des Chemins de fer tunisiens » recommend that the adhesion forces should always be verified, since they have suffered much on this acount.

The following values are admitted for the *width of the platform affected by the live load :* (see table following page).

In the case of skew bridges calculations are mostly based on the effective span of the small beams. Only the C. F. F. introduces a coefficient of reduction applicable to the moments arising from the live load, when the small beams are not set at right angles to the lines of support, in order to take into account the effect of the skew angle. This coefficient which varies with the skew angle, is based on results of soundings of structures in service. Systematic experiments are in course of being carried out with models of platforms of

Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzerland* C.F.F.	*Tunisia*
3.50 m subject to there being a minimum of 30 cm of ballast under the sleepers.	Single track : *width of platform* say 5.00 m for span $\geqslant$ 5 m. May vary from 5 to 3.50 m for $l < 5$ m. Double track : say 4.25 m between track centres.	$B = 3 + \frac{T - 3}{5} L$ in metres T = width of platform; L = span. B = T when $L \geqslant 5$ m.	Between track centres, say 4 to 4.50 m. Likewise accepted for single track.	Permanent load : n beams live load $n - 2$.	Single track : width of platform; Double track : half width of platform. Multiple tracks : width between axes of tracks.	Under each rail zone of $h + 50$ cm, where h = distance between upper surface of the platform and the tread of the rail.

full section (see part *b*: reinforced concrete). The C. F. F. hope to extend the results to bridges with the small beams embedded in concrete.

The *dynamic coefficient* is given by the usual formulae (see plate 2); the S. N. C. B. admit a constant coefficient = 1.30.

We have recapitulated in plates 19 and 20 some *constructional arrangements* practised on these systems. Denmark, Holland and Switzerland are levelling down the plinths of the rail bed to the upper level of the ballast in order to hold down the latter more effectively; the plinth moreover is a useful protection in case of derailment. The S. N. C. F. and Norway prefer to make a sloping embankment of the ballast in order to facilitate maintenance of the track and movements of employees. Tunisia adopts an intermediate method by levelling down the edges to the lower surface of the sleepers; the S. N. C. B. acts similarly to the first named Railway.

Opinions concerning the kind of plinths is divided. The Belgian, French and Norwegian Railways exclude cut stone, probably because of the cost (Norway) or because « the edges are not exposed to either shock or friction » (S. N. C. F.). Denmark, Switzerland and Tunisia prefer it in order to avoid cracks which inevitably occur at the edges of the concrete, and because it enables the copings to be extended to the edge of the platform. These divergencies of opinion arise partly from the particular form of the platform; the solutions adopted by the S. N. C. B. and the S. N. C. F. imply the use of reinforced concrete. The cut stone being expensive, the C. F. F. propose to supply prefabricated concrete copings and ultimately to use prestressed concrete.

Almost all the Railways support the beams on continuous metal fillets — often rails — which facilitate adjustement. The best solutions proposed for the remote ends of the platform appear to be the overhang and the elastic Belgian joint (See plate 20); the overhang system eliminates all risk of cracking the coping and returns the drainage to the back of the abutments.

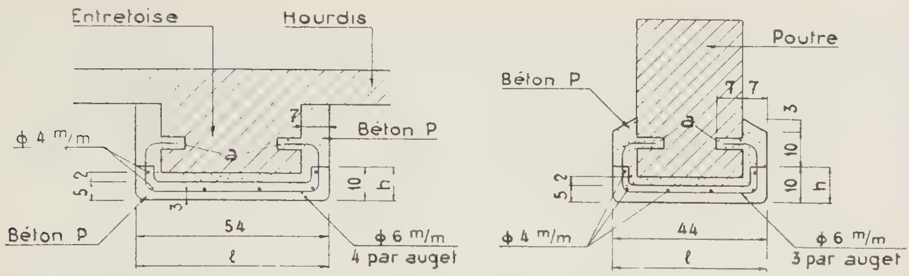
The method of reinforcing the platforms is still very much in the empirical stage; the following table gives some particulars of the reinforcements proposed :

Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzerland* C.F.F.	*Tunisia*
Vertically : ∅ squares 8 mm to 25 cm for minimum spacing of the beams. Longitudinal bars calculated for semi-encasing the platform.	Vertically : ∅ 12 mm every 20 cm across. Below (underneath the beams): squares ∅ 12-14 mm at 20 cm spacing allowing for embedding.	Vertically : ∅ 12-18 mm according to the span, $e = 30$ cm alternately on the beams and across the same. Below : ∅ 12-18 mm according to span, $e = 30$ cm across the beams.	Bars crossing the beams.	Single track : ∅ 8 mm every 20 cm (every 15 cm at the angles). Double track : no rules.	Vertically : 5 ∅ 12 per metre. Below (crossing the beams) : — single track : 3 ∅ 18 per m. — double track : 4 ∅ 18 per m. Increasing with the skew angle.	Vertically : ∅ 12 to 16 mm at 25 cm across. Below (underneath the beams) : allowing for embedding; calculated according to the adhesion.

The S. N. C. F. state that they « have verified that with these arrangements, the theoretical compulsion in the distribution bars and in the concrete is below the regulation limits for constraint ». The C. F. F. hope shortly, according to the tests already referred to, to be able to reinforce on a less empirical basis. The Emmenthal-Burgdorf-Thun Railway (Switzerland) contemplates 5 reinforcements 20 to 25 mm per m in the central part of bridges, as a transverse lower reinforcement plus an upper chequered area.

In the *skew work* the S. N. C. B., Norway and the « Compagnie Fermière des Chemins de fer tunisiens » generally speaking arrange the beams parallel to the tracks « in order to avoid the construction of Railway bridges at important junctions intended to take the strain of triangular abutments » (S. N. C. B.). Other systems make the orientation of the beams depend on the importance of the skew angle or the relation between the span and the width of the bridge. We reproduce on plate 21 the arrangement selected by the S. N. C. F.

The problem of embedding the lower flanges of the light girders is in dispute. Denmark, Norway and Tunisia continue to consider embedding in concrete; the Danes are calculating on 5 cm of concrete, reinforced with chequer work of iron ∅ 12 to 14 mm spaced in 20 cm mesh; the Norwegians work on 4 cm mesh; the Tunisian Railways bridges with embedded rails are provided with a network of 6 mm iron in 10 cm mesh. The S. N. C. F. work in principle on embedding, but allow the lower faces to be exposed when there is no fear of rapid corrosion due to smoke, provided that maintenance is facilitated. The S. N, C. B. only embed the reinforcement when the work is exposed to smoke. (Fig. 27.) Holland and Switzerland have abandoned the embedding, as they did not find this method satisfactory; the C. F. F. have pointed out that wherever they have completely embedded the beams, the concrete failed to adhere to the lower flanges and that this protection was nothing but



a = Openings to be drilled for securing the bars of the trough with cement mortar.

Length at troughs 40 cm.

Fig. 27. — *S. N. C. B :* Coating of the lower flanges of the troughgirders.

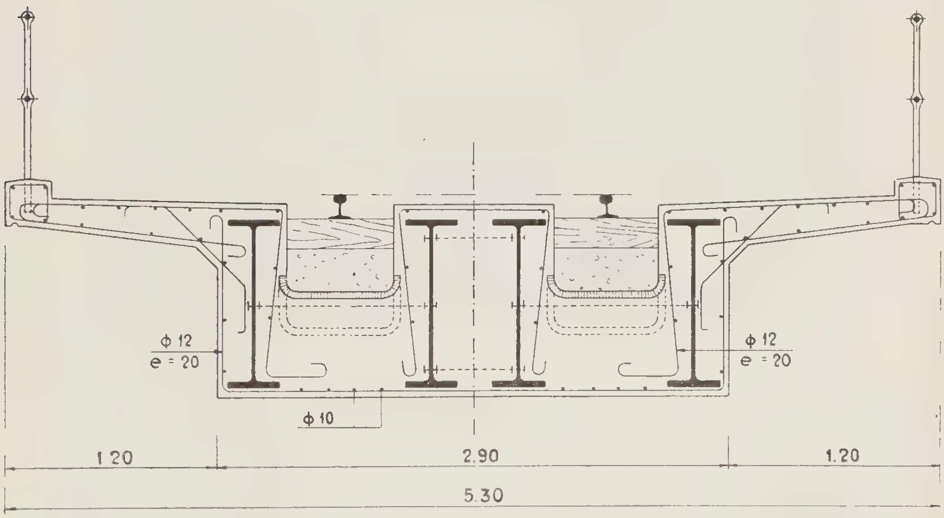


Fig. 28. — *Danish State Railways.* — Bridges with encased girders. Segmental construction.

Standard section.

Explanation of French text :

Entretoise = Rail tie bar. — Hourdis = Transom. — Béton P = Concrete P. — 4 par auget = 4 per trough. — Poutre = Beam. — 3 par auget = 3 per trough.

an illusion; a coating to be of any value calls for a thickness and a reinforcement such that the abolition of this method of construction would follow rapidly.

In the table below will be found some indications concerning the thickness of ballast, the design of the capping, etc.

The Emmental-Burgdorf-Thun Railway (Switzerland) add « Sika » to the protective capping of cement mortar. They allow as a minimum gap between the beams, half the width of the flanges.

The water is usually returned to the rear of the abutments. Drain pipes are not

	Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzerl.* C.F.F.	*Tunisia*
Minimum thickness of ballast	30 cm under the sleepers; same on curves.	25 cm under the sleepers; same on curves.	25 cm under the sleepers; same on curves.	25 cm under the sleepers; 12 cm minimum on curves.	40 cm under the rails.	40 cm under the rails; on curves minimum of 20 cm under sleepers.	40 cm under the sleepers for main lines.
Capping	Poured asphalt 20 mm Thin concrete : 40 mm	Bitumen jute : 5 mm Cement mortar : 40 mm	Capping of cement mortar 30 mm incorporated where possible.	Tarred felt : 2 layers. Reinforced mortar 50 mm	Tarred felt : 2 layers. Reinforced mortar : 30 mm	Bitum. jute : 2 layers = 10 mm Reinforced mortar : 40 mm	Lime mortar : 30-40 mm Poured asphalt : 15 mm Lime mortar : 30 mm
Minimum slope of capping	1 %	2.5 %	Generally 3 % At times 2 % crosswise.	2 % (rarely 1 %)	1 %	1.5 %	3 %
Minimum distance between flanges of beams	20 cm	No rule	17.5 to 24 cm according to height	30 cm	15 cm	15 cm	5 cm

used except for works having several spans or for works on the waterside.

As regards fixing the rails directly to the girders, there has not been much experience. The C. F. F. cite two applications, neither of which gives complete satisfaction because the junction is too rigid. The S. N. C. F. do not fix the rails to the beams but to the embedding concrete, under the same conditions as when laying the track direct on ferro-concrete platforms (See page 1675/85). The « Compagnie Fermière des Chemins de fer tunisiens » makes no reference to the subject, but we draw attention to their method of fixing to the beams of metal bridges (See page 1671/81 and fig. 16). Denmark has at times reverted to straight alignments for the flattened arch design as sketched in Fig. 28.

The double track bridges are preferably

built without joints by Holland, Norway and Switzerland; the transverse live load distribution covers a more extended area; probably the total load will be very small, so there is much less wear on the bridge. It is well understood that in consequence the transverse mountings must be provided in advance.

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from the S. N. C. B. which go in extensively for small beams embedded in concrete, for reasons already stated in the chapter on Railway bridges, almost all the systems proclaim the advantages of reinforced concrete, at least for *crossing over the running line*. The S. N. C. F. adds to this prestressed concrete, which they are tending to use more and more « on account of the facilities given by prefabrication for work to be done above the permanent way ». Tunisia likewise use prefabricated components. The C. F. F. built wooden over-bridges during the war, on account of the shortage of steel.

Fig. 29. — *Danish State Railways.* : Arched over-bridge.

CHAPTER VI.

Over bridges.

The *choice of the type of bridge* is ruled by several factors; soil of foundation, space gauge (loading gauge, etc.) available height (elevation of the roadway), number of points of support, visibility, aesthetical considerations, cost of construction and maintenance. Use of arched masonry bridges is restricted in spite of their manifest advantages from the point of view of maintenance costs, because of visibility limits and the gauge (Fig. 29); it is not advisable to adopt this type unless one can cross the rails at a considerable height. Metal bridges, with their high maintenance cost, are fairly expensive. Moreover apart

Among the different types of over bridges in ferro-concrete on normal gauge lines, the three span type has proved satisfactory in most cases (See figs. 30 to 33), except for example when there were existing abutments, or if in a rocky defile. The S. N. C. F. distinguishes 3 cases, according to the ratio of the thickness h to the span : ribbed decking $\left(\frac{h}{l} \text{ from } \frac{1}{10} \text{ to } \frac{1}{16}\right)$, tubular deck $\left(\frac{h}{l} \text{ up to } \frac{1}{25}\right.$ for a well-balanced contin-

Fig. 30. — *S. N. C. F.* : Typical over-bridge.

Fig. 31. — *Netherlands State Railways* : Typical over-bridge.

uous beam; a fairly expensive system) and the full slag for small thicknesses and spans less than 12 m. The C. F. F. recommend the full slab, which calls for a minimum thickness and is readily adaptable to curve and to moderate skew angles. The Tunisian Railways prefer a type of gantry with lateral overhang, in order to economise on foun-

Fig. 32. — *Swiss Federal Railways :* Typical over-bridge.

Fig. 33. — *Tunisian Railways :* Typical over-bridge.

dations. These types are applicable to crossovers at a skew angle so long as the angle is average (45 to 50°); beyond this the « covered section » type (See fig. 34) or the straight bridge with intermediate gantry supports are generally more economical.

The problem of *bridges which have to clear Railway stations* is more complicated. It is necessary to secure maximum visibility

and the least possible hindrance due to intermediate supports. The big spans are expensive when called for by the track layout or where modifications are expected later on. Holland and Norway prefer long spans in principle, as likewise do the Swiss, the latter however are limited to spans of the order of 30 m for economic reasons, a rule which has in practice not shown itself too much of a drawback. Reinforced concrete is usually employed; steel is however more interesting here than on main line work, as it lends itself more readily to modifications.

There are very few welded steel over bridges; Norway has a few full plate girders, up to 20 m span, with which they are well satisfied. Neither *special steels* nor *light alloys* have up to now been used.

Fig. 34. — *Danish State Railways :* Reinforced concrete over-bridge in « covered section ».

The majority of the systems provide metal over bridges with a coating of reinforced concrete supported by the metal framework (France) or by embedding the latter in reinforced concrete (Belgium, Switzerland); the C. F. F. recommend tying the platform to the longitudinal girders and tie bars, the moments in the covering being almost always positive in sign thanks to the elasticity of these components. Holland prefers a wooden decking. Tunisia employs its own system of prefabricated components, the occasion arising (see page 1708/118).

The watertightness and composition of the roadway on over bridges consisting of a reinforced concrete slab vary considerably, as will be seen from the following table : (see table following page).

There is generally no break in the roadway in line with the abutment on small bridges. The S. N. C. F. take the full slab or upper decking of T beams or box beams above the sea or bank wall (garde-grève). The roadway is only interrupted on bridges of a certain size; the C. F. F. do so in the case of bridges with moveable supports (slabs 20 m total length and all the girder bridges). The covering plate generally consists of hip-sheets. Denmark makes use of a device shaped like a double comb, the teeth of which interlock. The S. N. C. B. uses the elastic joint shown in plate 20.

Roller *supports* are only used when the span exceeds 20 m or so (25 m in Belgium and Holland); the S. N. C. F. uses rollers of hooped concrete. The limiting span is 15 m in Norway in the case of reinforced concrete bridges 10 m in Switzerland for all girder bridges. The S. N. C. F. do not make use of any expansion device on reinforced concrete bridges of less than 8 m span, nor do the C. F. F. if the span is less than 6 m. In the case of intermediate lengths, sliding rails or plates are used in nearly every country; it is recommended to center the stresses on the intermediate

Fig. 35. — *S. N. C. B.* : Over-bridge at Termonde Station. — Span : 197 ft.

Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzerland* C.F.F.	*Tunisia*
20 mm poured asphalt capping, 40 mm cement capping and mosaic paving laid on 3 cm of sand.	Watertight capping 5 mm thick and protective capping 40 mm thick or watertight capping of 3 mm and protective layer of concrete.	3 types (1).	Wearing surface of concrete or carborundum.	Thin asphalt or cement wearing surface.	Bituminous layer 20 to 40 mm for moderate or heavy traffic. For low density traffic, platform faced with hardening compound.	Cement capping and complementary capping in mortar (30 mm) plus a wearing surface.

(1) Bituminous coating (10 cm) : 6 cm bituminous coating and 4 cm under-layer of concrete, smoothed off.
(2) Mosaic pavement (16 cm) : paving-stones 13 cm, cement capping, smoothed off, 3 cm.
(3) Metalled (min. 23 cm) : minimum metalling 20 cm, smoothed off cement capping 3 cm.

piers by means of a narrower keyed-in centering plate, or by curved plates.

The *coefficient of increased allowance for dynamic effects* is smaller than in the case of Railway bridges, except in France where the same formula is used for all bridges, and in Denmark where this coefficient is 1.40 :

Belgium	*Denmark*	*France*	*Holland*	*Norway*	*Switzerland*	*Tunisia*
1.15 (French formula sometimes used)	1.40	$1.00 + \frac{2}{L+5} + \frac{0.6}{1+4\frac{P}{S}}$	$1.00 + \frac{40}{L+100}$	$1.00 + \frac{6}{L+10}$	$1.00 + \frac{5.5 + 0.05 \times L}{L+10}$	Like in France.

The S. N. C. F. however makes use of special modalities in applying the formula to reinforced concrete road bridges.

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CHAPTER VII.

Piers and abutments.

Opinion regarding the *piers* is practically unanimous : nearly everywhere massive piers of concrete masonry are preferred, with or without a facing of stone according to local circumstances in which aesthetical considerations play a great part. The profile must always be carefully studied in order to avoid any undermining.

Reinforced concrete is of interest above all in the case of the intermediate supports of under bridges, when the space taken up must be reduced as far as possible; visibility is increased by openwork piles (« palées ajourées ») (Fig. 36). The S. N C. B. most often uses reinforced concrete and states that financial savings are obtained thereby. In Tunisia, where the water regime is unusual, the Railway Company has found it necessary to replace the piers by double columns, polygonal or round (see fig. 37) fitted with a head beam; they have found that there are practically no eddies with such columns.

Metal columns are only used when there is question of reducing still further the thickness of the piles and increasing the visibility.

The question of lightening the *abutments* is controversial. The S. N. C. F. is of the opinion that this costs more than massive abutments in heavy concrete and that they « are less able to withstand effectively the braking effects; however they might be justified in cases where, being built in elevation on the natural level before an embankment (when doing away with level crossings for example), it is necessary to have a low unitary thrust on the ground ». The S. N. C. B. on the other hand has a lightened type of abutment with buttresses for its large canal bridges; Tunisia makes use of reinforced concrete wings 25 to 30 cm in the case of small bridges where the banks are not very high; the thrust of the soil is prevented by dry stone walling (see fig. 38). They consider in addition

Fig. 36. — *Swiss Federal Railways :* Sheet piling in reinforced concrete for underbridge.

Fig. 37. — *Tunisian Railways :* Bridge deck on concrete columns.

that it is essential to lighten the abutments in the case of large bridges, in order to reduce the unitary pressure on the foundations; but as it is an expensive matter to build hollowed-out abutments, this Company prefers the pier-abutment supporting a relieving arch.

Holland and Denmark use hollowed-out abutments, but in the latter country only in the case of important works.

Certain countries (Denmark, Holland, Norway) systematically make use of *return walls* in preference to *wing walls;* these are more economical, especially if the foundations are costly, and can endure a greater horizontal thrust. Switzerland prefers wing walls, except in special cases; although they are more expensive, they guide the water better and are relatively independent of the body of the track, which facilitates maintenance; they must be made to flare out to a greater or lesser extent in the overhang (fig. 37) doing away with the walls.

Isolated bearings in hewn stone, which lead to dislocation of the masonry, have in all cases been supplanted by *supporting banks* in reinforced concrete which distribute the load, assure the binding of the upper part of the piers and abutments and readily lend themselves to any desired shape.

The *fixed supports* are generally sited on the abutments, especially in the case of

Fig. 38. — *Tunisian Railways :* Abutments (« en voiles »).

case of bridges over roads to improve visibility and give the impression of better clearance. On the S. N. C. B., S. N. C. F. and the « Compagnie Fermière des Chemins de fer tunisiens », each case is studied on its own merits, according to its situation. Return walls are generally made in one with the abutments, whereas wing walls are often separated by a joint; this is not an absolute rule however, as the strength of the foundation soil, the probable earthworks and the way the work is to be carried out, all have to be taken into account. It may be mentioned that in the case of reinforced concrete slab bridges, Tunisia sometimes extends the slab and makes it important works. In certain cases (bridges with discontinuous spans), they have to be sited on the piers, and no disadvantage accruing therefrom has been reported. It is generally agreed that the sum total of the horizontal forces acting on the bridge are transmitted to the foundations, but usually without dynamic effects; the C. F. F. estimate that if the support is placed on an abutment with deep foundations, only a fraction of the forces can be transmitted to the foundations, a fraction which has to be estimated in each individual case.

In Tunisia, where the water regime is unusual, the Tunisian Railway Co. makes a distinction between the « minor » and

Fig. 39. — *Tunisian Railways :* Filling over pipes (leat type).

Fig. 40. — *Tunisian Railways :* Latticed filling.

« major » bed; the former with « a permanent flow of water makes it essential to provide foundations which cannot be undermined, in spite of the constant presence of water; this is not the case with a « major » bed when the water flow is intermittent, and only occurs on certain days of the year ». The « leat » type of work (fig. 39) or the « lattice filling » type consisting of a reinforced concrete apron resting on about 75 cm of heavy concrete (fig. 40), are economical types, and fulfil the desired object very satisfactorily.

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CHAPTER VIII.

Sounding bridges.

Bridges are generally tested with two general objects in view :

a) *Check tests,* generally carried out before the bridge is put into service, intended to reveal any constructional defects or abnormal behaviour. Most Railways carry out such tests on all Railway bridges, except sometimes masonry arches, which are only sounded when there appears to be some particular value in so doing. Such tests consist essentially in measuring the versines, and in certain cases the stresses. The C. F. F. complete their tests shortly before final acceptance of the bridge, i. e. about two years after it has been put into service, by extensive soundings including measuring the static and dynamic stresses; the object is to determine to what extent the theoretical calculations and actual behaviour in service agree. Periodical tests are rarely made; Holland recommends them in the case of metal bridges of a certain age, at intervals based on the condition of the bridge. The C. F. F. are of the same opinion; they also make a check every five years, by taking levels, of the deflection of certain Railway bridges under permanent load to discover if there are any deformations;

b) *Special soundings made to clear up certain special points.* — Such soundings are necessary to ascertain the condition and real strength of a doubtful bridge; they can be of very great value. But one of the most interesting aspects of sounding bridges lies in the fact that they can help to solve certain special problems where calculations are useless : partial encasing, distribution of the load, part played by so called accesssory components, distribution of the stresses between the rails of a multiple trellis, etc. Today, thanks to the many static measurements made in more or less every country, certain problems, such as the distribution of the static stresses on current bridges, can be considered as solved. As extensive soundings are very costly to make, there is no point in proceeding indefinitely with operations which will not throw any new light on the question, but the Railways should concentrate on those questions which have not yet been finally settled. For example the S. N. C. F. and the C. F. F. both propose to study further, by measuring systematically, the dynamic effects of live loads.

Side by side with the well known mechanical apparatus, both recording and otherwise, such as flexometers, extensometers and clinoscopes of current types, the following apparatus were mentioned by some Railways :

— *to measure the static action of liveloads :*
capacity condensers (« condensateurs capacitifs ») (Holland);
Coyne acoustical extensometers (S. N. C. F.); comparator (S. N. C. F.);

— *to measure the dynamic action of liveloads :*
optical flexometer (S. N. C. F.); rolling-recorder (« rouligraphe ») (S. N. C. F.); small vibrograph (C. F. F.);

— *for slow deformations, due to contraction :*
Coyne recorders with vibrating cord (S. N. C. F.); comparator (C. F. F.).

In addition, Holland and the S. N. C. F. have *ohmic resistance apparatus;* the C.F.F. and Norway are obtaining such equipment. This is a considerable step forward; their very small size makes it possible to take soundings with *strain gauges* in places inaccessible to mechanical instruments; they do not set up any vibrations of their own, which is a great advantage when measuring dynamic actions; they make it possible to measure the contraction (« fluage »).

As regards measuring the existing stresses in a given bridge under the effect of the permanent load, the C. F. F. report that in the case of metal bridges it is possible to drill a hole in the part in question and measure the relaxation stresses in three directions around such a hole. It is then possible to deduce therefrom the initial stresses (see the article by M. W. SOETE in *Ossature métallique,* No. 5, May 1948).

The use of delicate instruments of this

type, which are often extremely complicated in construction, is making it more and more necessary for the Railways to confide such tests to specialist staff.

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CHAPTER IX.

Other structures.

a) *Platform roofs.*

In all cases the platform roofs take the form of a shelter.

Steel is the most widely used material (fig. 41); welding makes it possible to obtain an elegant, light roof (fig. 42); erection can take place very quickly, and there is nothing to get in the way; adaptations can easily be made later on. Norway also uses wood, which was also used in Switzerland during the war (fig. 43).

Reinforced concrete simplifies the question of roofing, and looks like leading to reduced maintenance costs. It has not yet been used systematically, except in France where the S. N. C. F. use it on the same scale as steel, without any preference one way or another, according to the economic conditions of the moment. In 1926, they designed the reinforced concrete roof with a curved decking, but have now gone back to plain decking which is considered aesthetically more pleasing (See fig. 44). The S. N. C. B. has built two trial roofs in reinforced concrete (fig. 45); they are satisfied with the result but « experience has shown that it takes considerably longer to make these reinforced concrete roofs than the roofs with metal framework ». The other Systems in their turn are considering the use of reinforced concrete. There are no outstanding examples to report; Holland is designing reinforced concrete platform roofs for the new station at Leiden « in arched form ».

Apart from Holland which is considering the use of skylights in future constructions, all the Railways have given up using glass in separate roofs, as there is sufficient lighting from the sides.

The *dissymetrical loads* allowed for in the calculations vary from country to country; in some only wind loading is taken into account, in others both wind and snow loading, sometimes with a certain reduction :

Belgium	*Denmark*	*France - Tunisia*	*Holland*	*Norway*	*Switzerland*
Wind loading : 100 kg/m² at 10° to the horizontal.	*Wind* : dynamic pressure of 80 kg/m² and coefficients from tests : + *snow* partly applied in unfavourable sites.	*Wind* : dynamic pressure 30 to 50 kg/m²; coefficients from tests : $+ \frac{1}{2}$ *snow* partly applied (difference limited to 30 kg/m².	*Wind* : dynamic pressure 70 or 85 kg/m²; 100 kg on the sea coast.	*Wind* : 150 kg/m²; + *snow* dissym. 100 kg/m².	*Wind* : dynamic pressure 70 to 85 kg/m²; coefficients from tests. *or snow* : p on one side and $\frac{p}{2}$ on the other side.

Fig. 41. — *Danish State Railways :* Metal platform roof. — Width : 26 feet.

Fig. 42. — *Swiss Federal Railways :* Metal platform roof. — Width : 31 feet.

Fig. 43. — *Swiss Federal Railways :* Wood platform roof. — Width : 22 ft.

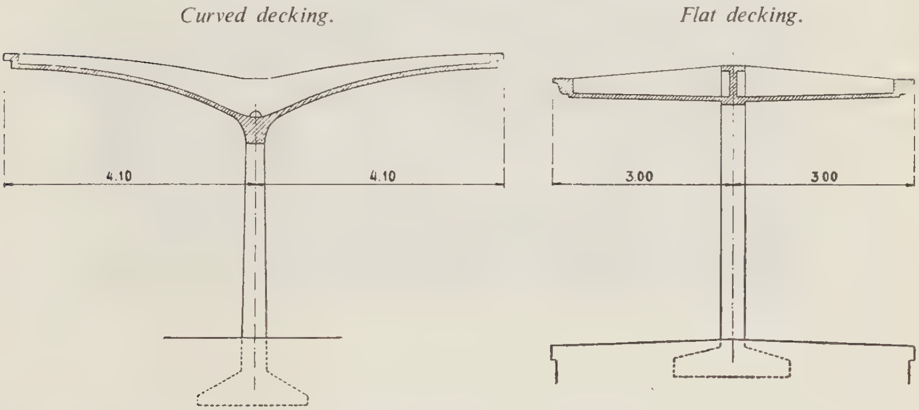

Fig. 44. — *S. N. C. F. :* Reinforced concrete shelters.

b) *Retaining walls.*

Semi-empirical formulae are still in current use to determine the earth thrust. On the other hand more scientific methods are ever being used to calculate the strength of the soil : load tests, geotechnical investigations. The S. N. C. F. uses the methods explained by Resal and M. Caquot in their study of soil mechanics.

c) *Tunnels.*

Protection of the concrete coverings against corrosion due to smoke.

The Danish State Railways use two layers of a solution of 80 % lead fluosilicate and 20 % water (Pb. Si. F6 or Pb F^2 Si F^4). When there is particular risk of corrosion, they use a solution of asphalt cold.

The Tunisian Railways have made the cement covering flush; in 1939 they constructed a tunnel entirely of « Pelloux » cement concrete, specially intended for use with calcarious water and water containing sulphur.

Protection against short circuits on electrified lines.

In Denmark the insulators are cleaned at frequent intervals. The S. N. C. F. stipulates a flush finish and water repelent covering around the plates of the suspension elements. The C. F. F. make the joints in the masonry flush by Sika 3; on the rock face, Sika 4 or Sigunit capping 50 cm on each side of the supports or lines; the C. F. F. also increase the insulation (7 kg instead of 5 kg) insulators, and periodic maintenance; they make use of materials less liable to oxidize : bimetallic carrier-cable with copper casing, galvanised or plumbed ironwork covered with copal varnish, suspension lugs and cleats in bronze.

Summaries for part a).

There is unamity of opinion concerning the theoretical liveloads allowed. The question of the dynamic stresses on the other hand still needs clearing up; it would be a good thing if systematic tests could be undertaken to bring out separately the effects of the various parameters : type of bridge, span, speed, condition of the track and rolling stock, etc., and to ascertain the actual stresses in the materials.

The choice of the kind of bridge depends upon technical and economical considerations (future maintenance costs must not be overlooked), as well as the aesthetical point of view.

Metal bridges. — The metal bridge is of interest in the case of very long spans or if the height available is very limited; likewise when special assembly conditions are involved, or when the foundation soil makes it necessary to have the smallest possible reactions and a certain flexibility in the bridge.

The construction should be very simple :

Fig. 45. — *S. N. C. B. :* Ferro-concrete platform roof at Brussels-North Station.

plate web girder up to 35-40 m single span, 50 to 60 m as a continuous girder. Beyond this span, trellis girders with a wide lattice and single diagonal. Small girders with wide flanges will be used for the lattice rails, longitudinals and stays. Special systems such as Langer girders, bow-string, cantilever, and Vierendeel, as well as multiple lattice girders must be reserved for very special cases.

Reinforced concrete slabs to cover metal bridges are an interesting solution; they improve the riding of the stock, reduce the vibrations of the bridge and simplify construction. Laying the track directly on the concrete decking, once it has been satisfactorily carried out, will make it possible to retain all these advantages and at the same time make an appreciable saving in the height required and in the dead weight. In bridges with a lower track (lateral beams) it seems preferable definitely to separate the plate from the girders, as it is difficult to join them up satisfactorily. On the other hand, it is much easier to do so in the case of bridges with an upper track (girders underneath); full advantage can be taken of the presence of the slab and a combined concrete-steel girder made, which will no doubt be the solution utilised in the near future for this category of bridge, and for spans up to 30 or 40 m, as soon as certain problems in connection with the contraction and lasting efficiency of the joints have been solved.

The present stage of development of the technique does not allow of the welding of bridges — especially Railway bridges — of any size, no matter what kind of steel is used. It is possible however to make use of welding for 30 to 40 m span plate girders in mild steel, A 37 to 44 (thickness of the plate up to $\sim$ 50 mm) which leads to a slight reduction in the weight and consequently probably to lower maintenance costs. These advantages are practically non-existent in the case of trellis girders so long as it is impossible to let the fastenings be welded. It is permissible to hope however that both metallurgy and welding technique will make such progress in the future that it will soon be possible to have entirely welded bridges; this would mean monolithic steel bridges, with rigid assemblies; this makes the question of the polyaxial stresses even more acute, which few Railways think it opportune to take into account as yet.

The use of special steels is limited owing to their high cost, their weakness under repeated stresses, and the difficulty of welding them. They are of interest at the present time in the case of very long spans — under certain conditions — in places where the factor « transport » has a great influence on the cost (Colonies). Light metals have the same drawbacks, to an even greater extent, as well as great deformability; they can only be considered in very special cases. The development of these techniques is closely bound up with the idea of the real fatigue of bridges and the influence of the time factor on this phenomenon, the fatigue being taken into account in certain countries being the result of laboratory tests which bear no relation to the modalities under which the loads occur on bridges in actual service. It would be advisable to clear up this point, even in the case of mild steel, if only to obtain more uniform margins of safety.

Arched masonry bridges of concrete or stone. — This type of bridge in spite of its antiquity is still being built. It is the original type of bridge; its reserve loading is very great and its maintenance very low. It is used whenever local conditions permit : nature and configuration of the ground, gauge, thickness available, being built under a line in service, etc. Openings of the order of 100 m are perfectly conceivable, so long as the arch can be made proportional in height and shape, and the foundation soil is suitable.

Stone bridges are the most beautiful, and stand up to bad weather better than concrete. It is not necessary to build such bridges on a luxurious scale however. If

stone is too dear, experience shows that the mixed type can very well be adopted, i. e. a concrete bridge with stone facings; there is no disadvantage in combining the two materials. It would however be interesting to have a more certain knowledge of the modulus of elasticity of stone bridges.

Articulations should only be considered when local conditions (foundations) make them essential.

Bridges of reinforced concrete (see summaries to part b). — Reinforced concrete Railway bridges are widely used on all Railways; they include full slab, arched and straight girder bridges; all the Railways report that they have found them satisfactory, apart from certain reservations in the case of the latter category.

Reinforced concrete appears to be the best material for overbridges, in the form of continuous girder or slab bridges with three openings.

Already prestressed concrete is proving of value in the construction of overbridges; in the case of Railway bridges it will be necessary to wait until the concrete can be given a higher rate of work (see summaries for part *c*).

Bridges with joists encased in concrete.— The advantages are simplicity and rapidity of construction; they make it possible to decrease the height of the bridge as compared with reinforced concrete decking, and to reduce the amount of scaffolding required. They are expensive however; so it is not possible to consider them, unless the above mentioned advantages are of paramount importance.

The limiting span is about 20 m.

The method has some disadvantages; it is essential that the transversal reinforcement be such that there is no danger of dislocation. There is no advantage in making the compressed concrete take part of the load, but the adhesion and tension of the concrete must be carefully checked; the « ribbed » type is not rational.

Piers and abutments. — Massive concrete structures are the most satisfactory type, with or without stone facings. The hollowed out abutment of reinforced concrete is fairly expensive, but its use is justified when it makes it possible to decrease the pressure on the foundations.

Reinforced concrete or steel columns are only of interest when they make it possible to reduce the space needed and increase the visibility (under-bridges); in some cases they also make it possible to decrease the eddy.

Platform roofs. — Steel is the material most often used for such roofs, since it enables light constructions to be used, which can easily be adapted as required. Trials of reinforced concrete have proved satisfactory however, and the development of this technique offers possibilities. Wood should only be used in the case of well sheltered roofs, and for temporary structures.

Sounding bridges. — Soundings can be used either to check bridges, or to carry out research into special questions. A great deal has been done in this latter field regarding the static effects of loads; the new apparatus now available will make it possible to tackle other problems, such as retarded actions, of the contraction type, and dynamic stresses.

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b) Results obtained in the construction of railway bridges in reinforced concrete.

The first reinforced concrete Railway bridges date from the beginning of the century; full or ribbed slabs of very moderate spans, were built in Switzerland between 1900 and 1903; 35 × 100 cm girders with 15 cm decking in 1905 in France, for spans of 8 to 9.20 m.

The Dutch built the 1 920 m long Rotterdam Viaduct in 1906 with continuous arcs of 7.50 m up to 20 m spans. At the same date the Swiss built the bridge over the Rhone at Chippis for an industrial line;

Fig. 46. — *S. N. C. F. :* Reinforced concrete railway bridge over the Loire at Orléans. Tubular continuous decking of varying inertia. — Max. Span : 155 ft; total length : ~ 1 444 ft.

Fig. 47. — *Swiss Federal Railways :* Lorraine viaduct at Bern. — Total length : ~ 3609 ft.; 4 tracks. — Span of arch over the Aar : 492 ft.

this is an encased arch of 60 m opening with a suspended deck. The first applications in Norway, Denmark, Belgium and Tunisia were at a slightly later date.

The epoch at with reinforced concrete came out of the experimental stage to become a standard material in the construction of Railway bridges is variously given by the different Railways of the group : Holland dates the first applications to 1906, Denmark and Norway to 1915; in France, this epoch is around 1920 to 1930 in the case of arch bridges and 1930-40 for bridges with straight girders. Belgium gives the date as 1930 and Switzerland as 1937; in Tunisia, it was not until the last war.

Though interesting bridges were built between 1910 and 1935, it must be recognised that the increase in the price of steel in the years prior to the last war, and above all the destruction which took place and the shortage of materials resulting therefrom, are the essential factors leading to development of reinforced concrete Railways bridges. A whole series of noteworthy bridges have been erected in France : girders of up to 47 m span (bridge over the Loire at Orleans, continuous tubular bridge, 7 beams of varying inertia see fig. 46) and many arches : Longeray on the Rhone (main opening 69 m, height ~ 60 m; a three girder bridge joined above and below by decking); Nogent-sur-Marne (3 encased arches of 80, 70 and 67 m); the Jonneliere viaduct (arch with two articulations 95 m long lightened by 3 longitudinal alveoli, carrying a full slab deck); Neuilly-sur-Marne (main opening of 67.50 m with three articulations; the upper decking is under the track; the outer partitions form the spandrels); finally the Chasse Viaduct over the Rhone with a main arch of 124 m. In Switzerland, there is the Lorraine Viaduct at Berne, about 1 100 m long, which includes an encased caisson of 150 m span to take four tracks (see fig. 47). Denmark can show the entry bridges to the Little Belt Bridge (see fig. 48); Norway reports articulated arches of 52 m which are encased.

The use of reinforced concrete for small and average sized Railway bridges is reported by every country (fig. 49).

The *full slab* is an excellent solution up to a limiting span given as follows by the different Systems :

Belgium	*Denmark*	*France*	*Holland*	*Norway*	*Switzerland*	*Tunisia*
~ 15 m	~ 12.50 m	11 m	8 to 10 m	10 m	simple : ~ 14 m continuous : ~ 18 m	3 to 4 m

The full slab is perhaps rather on the heavy side as soon as the span exceeds a few metres; it has many great advantages however; simplicity of erection (casing or shuttering, reinforcing, concreting); great transversal rigidity, and consequently a good distribution of the live loads; a large reserve of load; unaffected by dynamic stresses and fatigue effects, owing to the high dead weight; stresses in shear and oblique stresses of low tension, and consequently less risk of cracks occurring, and easily adapted to skew and curved bridges. Its field of use should therefore be extended as far as possible. The articulated or encased frame enables the thickness of deck to be reduced (fig. 50); for small spans on weak soils, the completely closed in tube or frame is of interest.

Beyond the spans given above, when the full plate bridge would obviously be too heavy and costly, the section is increased by adopting the T section or caisson, which gives a *straight beam*. Bridges of this type built or proposed by the different Railways are tabulated below :

Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Holland*	*Norway*	*Switzerland* C.F.F.	*Tunisia*
Built : caisson $l = 15.54$ m. Proposed : $l_{max} = 15$ m	Built : caisson : $l = 14.75$ m.	Built : continuous caisson : $l_{max} = 47.20$ m Proposed : $l_{max} = \sim 30$ m	Proposed : simple beam : $l_{max} = 15$ m. continuous beam : $l_{max} - 18$ m.	Built : simple T beams = 19 m. continuous T beams = 17 m. Proposed : simple beams : $l_{max} = \sim 25$ m. continuous beams : $l_{max} = \sim 30$ m.	Built : continuous T beam : $l = 27$ m.	Built : bridge with lower track, semi-parabolic lateral beams reinforced by rails, $l = 15$ m.

The caisson is better than the T section; the greater mass of concrete in the parts under stress lessens the danger of cracks occurring; transversal rigidity is greater, and consequently there is a better distribution of the live loads. The S. N. C. F. provides two ribs per track; on the Swiss Lorraine bridge (T section) there are four ribs for the 4 tracks, i.e. one in the centre of each track.

The weakness of the straight beam lies in the fact that the concentration of the dynamic stresses in the ribs soon gives rise to shear effects and above all to oblique tension stresses which can become dangerous. The S. N. C. F. which has had a great deal of experience in the matter and has been bold enough to build tubular bridges up to 47 m span, is now going back to more modest figures (30 m). It should be noted that it is possible to counteract the oblique tension stresses in continuous beams with a varying moment of inertia by carefully designing the shape of the beams.

Bridges with low level track and lateral beams are only recommended in the case of short spans, when the height available puts a full slab out of question (fig. 51); the width of the compressed elements is necessarily restricted, which makes this method uneconomical. In addition these elements are more or less under tension, the structure lacks transversal rigidity, and suffers from vibrations. *Trellis girders* are definitely out of the question, in imitation of metal bridges, owing to the many elements under tension.

The « *cantilever* » bridge is of no interest, except in very special cases where the nature of the soil calls for an isotatic system. The reduction of the section in the case of the supports of the separate deck leads to stresses in shear of high value; the presence of articulations or secondary supports is never desirable, as this does away with the monolithic character of the bridge.

The main field for reinforced concrete is the *arch*, where compression stresses preponderate; not arches of the shape or size that can be built in masonry, but when the

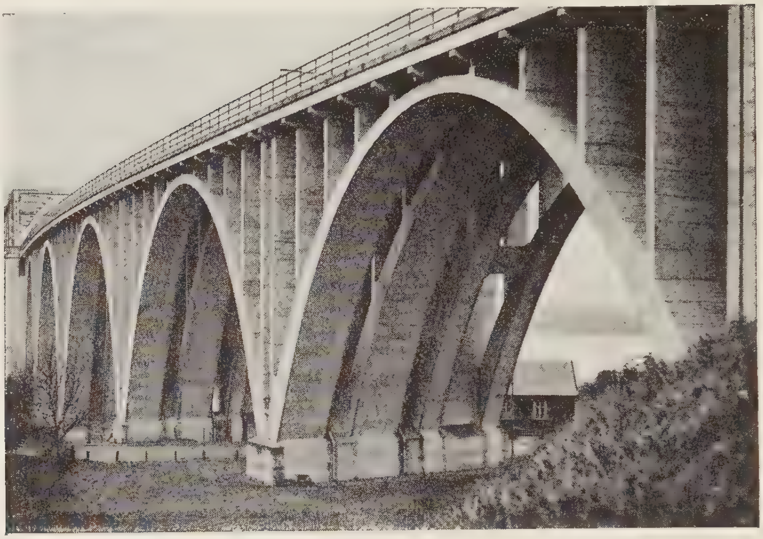


Fig. 48. — *Danish State Railways :* Access bays to Little Belt bridge.

Fig. 49. — *S. N. C. F. :* Bridge at Mourepiane. Continuous, variable inertia girders.
Max. span : 94 ft.

Fig. 50. — *Swiss Federal Railways :* Full section frame underbridge. Skew span : 44 to 55 ft.

Fig. 51. — *Tunisian Railways :* Lateral girder bridge; center span : 49 ft.; side spans : 26 ft.

span or the surbasement makes it impossible to avoid tension stresses or when the load on the foundations has to be reduced. (Figs. 47, 48, 52.)

The *calculation* of reinforced concrete Railway bridges is based on the classical theory in every country : Navier hypothesis, section made homogeneous by means of the

coefficient of equivalence of the moduli of elasticity, concrete with cracks under stress. The allowable stresses are a certain percentage of the strength of the cubes or prisms of the concrete and the elastic limit of the steel. This is a very simplified method, which gives no real idea of the safety. Unfortunately at the present time, it is difficult to find any better method; but we may ask ourselves if in fact the determination of the allowable stresses by tests carried out on models would not be a better method, at least in the most usual cases.

The S. N. C. F. points out that « for steel percentages lower than the critical percentage (which is still poorly defined) generally used, breaking depends on the elastic limit of the steel and not on the resistance to compression of the concrete »; they intend to introduce this point in their regulations.

The *width over which the live load is distributed* on slab bridges varies from country to country :

Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F. *and Tunisia*	*Holland*	*Norway*	*Switzerland* C.F.F.
3.50 m	length of the sleeper plus the distribution at an angle of 45° between the underside of the sleeper and top of the slab.	$B = 3 + \frac{T - 3}{5} \times L$ in m for $L > 5$ m ; $B = T$ L = span of the bridge T = width of the slab.	$B = \sqrt{(0.75 \times l)^2 + b^2}$ l = width of the slab b = distance between rails + the distribution at an angle of 45° up to the neutral axis of the slab. B_{max} = distance between tracks.	According to the regulations of the Norsk Standard. NS 427.	Width of the slab.

In the case of ribbed bridges, the S. N. C. F. « allows the static ratio of the loads on the beams » except in certain special cases in which the transversal elasticity of the deck is taken into account. The C. F. F. take this elasticity into account; they are of the opinion that uniform distribution could probably be allowed for in the case of caisson beams.

Skew bridges are generally calculated according to the oblique span, except in the case of « covered sections » (fig. 53) with a large amount of skew, when the straight span is taken; Denmark frequently makes use of an intermediate solution in the case of bridges very much on the skew, by increasing the width of the bridge and limiting the angle of intersection of the work to about 60°. The siting of the main reinforcements depends upon the span allowed for in the calculations.

The C. F. F. have long noticed when

Fig. 52. — *Danish State Railways :* Arched reinforced concrete underbridge.

Fig. 53. — *S. N. C. F. :* Type of covered section. Straight span = 56 ft.; Skew 32°57′30″.

making tests of the load, that the real stresses do not coincide with the theoretical ones. The skew leads to torsion effects which these full slabs, which are very rigid, are strong enough to stand, but which modify the value and direction of the principal moments. To clear up the question, the C.F.F. have asked the Static Laboratory of the Polytechnical School of Lausanne University to carry out systematic tests on small scale models. The programme covers 15 cases, with 5 angles of intersection : 90°, 75°, 60°, 45° and 30° for three values of the ratio between the skew span l and the width of the bridge on the straight : $\frac{l}{b}$ = 1, 2 and 3. Different loads will be used.

These trials are still in hand. Plate 22 gives the values ascertained for M_1 and ψ_1, M_2 and ψ_2 in the case of a load uniformly distributed over the whole of the slab. With such a load it is found that :

1) The value of the principal moment is practically independent of the ratio $\frac{l}{b}$ at least within the limits considered. The moment M_1, related to the straight span l' exceeds the value 0.125 pl'^2 to an increasing extent as the skew increases, as the table below shows; this is due to the ratio of the load of the end triangles on the centre part.

Skew	90°	75°	60°	45°	30°
M/pl^2 average of tests	0.124	0.117	0.100	0.078	$l = b$: 0.041 $l = 3b$: 0.050
$\sin^2 \alpha$	1.000	0.933	0.750	0.500	0.250
M/pl'^2	0.124	0.125	0.133	0.156	$l = b$: 0.164 $l = 3b$: 0.200

2) The direction ψ of the principal moments in the centre of the plate depend on $\frac{l}{b}$ when $l = b$, this direction is practically perpendicular to the abutments; the angle β increases as the ratio $\frac{l}{b}$ and the skew increases, without however reaching the bisector $\frac{90-\alpha}{2}$ of the angle (90-α) formed by the normal to the lines of support and the edge of the slab. Very approximately, we get :

$$\text{for } l = 2b \qquad \beta = \frac{90-\alpha}{4}$$

$$\text{for } l = 3b \qquad \beta = \frac{90-\alpha}{3}$$

3) At a distance e from the edge of the slab equal to its thickness, the principal moment M_2 is already no longer parallel to the edge; the angle ψ^2 is an important fraction of ψ^1, from 40 to 85 %; it increases with the skew but has little relation with the ratio $\frac{l}{b}$

It must be made clear that the moments M_1 and M_2 are the maximum moments at the points in question; but it is possible that there are stronger moments at other points.

The tranversal moments in the centre of the slab, measured perpendicularly to the free edges (always in the same case of a uniformly distributed load) have the following values (multiples of pl^2) :

α =	90°	75°	60°	45°	30°
$l = b$	0.026	0.036	0.043	0.048	0.033
$l = 2b$	0.013	0.019	0.020	0.031	0.025
$l = 3b$	0.014	0.015	0.020	0.027	0.016

Other conditions of load are under investigation as well as certain special points.

The question of the *dynamic effects* in reinforced concrete Railway bridges requires systematic investigation; in the meantime the Railways make use of the formulae given in plate 2; the divergencies are still more marked than in the case of metal bridges (see plate 4).

Apart from the Tunisian Railway Company, who mention a small bridge for loading minerals built in 1912 which cracked under an overload of 40 %, no Railway has reported any serious *defects* in reinforced concrete bridges. This is an encouraging fact. On the other hand many less serious defects have been noted : cracks due to excessive shrinkage or failure to appreciate the monolithic character of the bridge, i.e. its real behaviour in service; local corrosion of the reinforcement insufficiently covered by porous concrete. To avoid similar defects, the following rules must be observed :

— good quality concrete must be used, with a satisfactory resistance to tension;

— the reinforcements must be suitably arranged : small diameter reinforcements laid close together; sufficiently covered by the concrete;

— the shrinkage must be reduced by choosing cements with a low shrinkage value and by the way the concrete is made (minimum amount of mixing water, ulterior humidification); the proportions of the mix must not be exceeded; whenever possible the joints in the concreting should be as close together as possible and left open as long as possible;

— sufficient reinforcement must be provided in all parts under stress; the fact that certain elements are left out of the calculations does not mean that they do not take any of the stresses;

— use undeformable supports, both for the scaffolding and curve pieces.

Plate 23 sums up the characteristics of the *concrete* used for reinforced concrete Railway bridges as prescribed by the different Railways. Nowadays it is possible to make good quality concrete if certain elementary precautions are taken : high grade cement of regular quality; clean aggregate, non frost-cleft, free from shale and clay; carefully studied composition, depending on the aggregates available, which is closely followed (discontinuous granulation often gives better results than continuous granulation, especially when the concrete is mechanically packed); the different aggregates must be carefully measured and the correct amount of water used; the concrete must be correctly mixed and regularly vibrated; new concrete must be kept damp over a sufficiently long period. Very high compression strength will only be aimed at when it is really necessary, as it is often obtained at the expense of other qualities; good resistance to tension is always to be recommended in order to decrease the risk of cracks. If too much cement is used, shrinkage is increased.

No Railway has issued special regulations *for structures exposed to bad weather;* in every country it is considered a sufficient precaution to have good compact concrete and properly covered reinforcements. The minimum covering varies as shown (in mm) in the following table :

Belgium	*Denmark*	*France*	*Holland*	*Switzerland*	*Tunisia*
30 mm	30 mm except*ly*. 40 mm	30 mm $e = \varnothing$ for $\varnothing > 30$ mm	35 mm	non exposed structures : 20 mm exposed : 30 mm	20 mm except*ly*. 35 mm

The advantages of *vibration* are no longer disputed. Internal vibration is generally used; care must be taken to see that it is regular; sometimes the framing of small elements is also vibrated.

Special cements are not used, except sometimes cement grouts in Tunisia for foundations (calcarious water and water containing sulphur), and perhaps cements containing a small amount of slag in France; these do not call for any special remarks.

Products intended to improve the handling qualities of the concrete are not in current use. The C. F. F. used « Plastiment » during the war to save cement; in normal times there would be no special point in using it. Tunisia has tried « *Kiselghur* » and states that it definitely improves the handling qualities and water-tightness. No experience as regards air feeders.

The *reinforcements* are generally made of mild steel, 37 to 42 kg/mm² (23.49 to 25.40 tons per sq. in.) approx. breaking strength, 24 kg/mm² (15.24 t per sq. in.) elastic limit. Welded joints are usually permissible, provided there is a reduction in the stress; they are exceptional in Denmark and the S. N.C. F. doet not allow them under tension unless « it is impossible for the concrete section to hold reinforcement and its covering ».

The use of special steels is no longer exceptional, although not current practice. The S. N. C. F. use a steel with 32 kg/mm² (20.32 t per sq. in.) limit of elasticity, preferably in structures where the actual

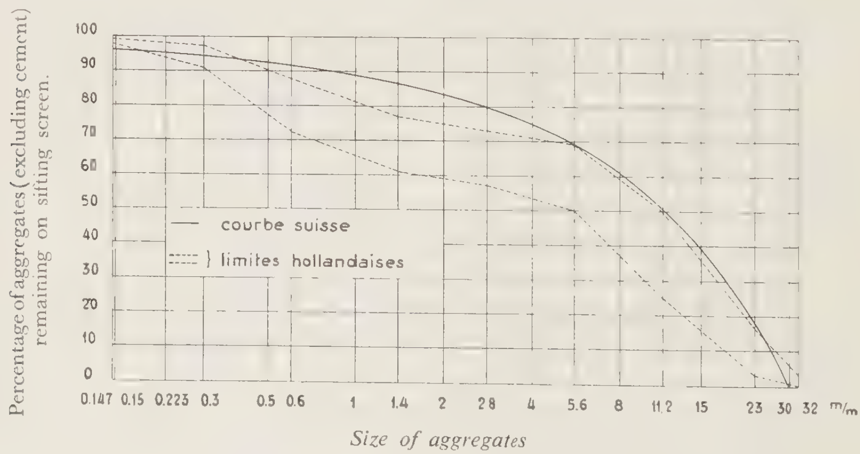


Fig. 54. — Reinforced concrete for railway bridges. *Dutch* and *Swiss* granulometric consistency.

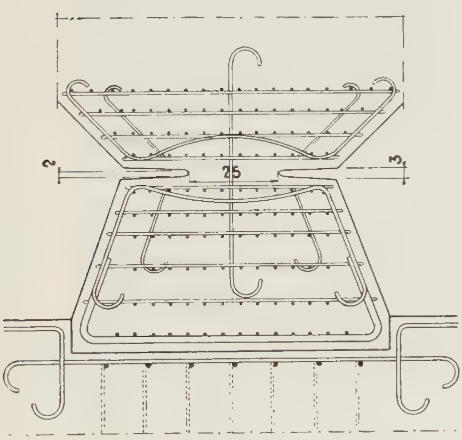
Explanation of French text :

Courbe suisse = Swiss curve. — Limites hollandaises = Dutch limits

weight is high in proportion to the variable live load. Denmark goes up to 42 kg/mm² limit of elasticity; Holland reserves special steels for components not directly submitted to the action of liveloads. Switzerland has used special steels; in the future she intends to use above all bars with an elastic limit increased by cold-drawing which results in better adhesion. Tunisia uses rails on a wide scale.

The breaking strength of reinforced concrete normally depends not on the concrete but on the steel — as is well known — so it is of interest to increase the stresses in the reinforcement; unfortunately, this also increases the risks of cracks forming and adhesion stresses; as special steels, being smoother, have in addition less good adhesion than ordinary steel, their use is limited. On the other hand, steels whose elastic limit has been increased by cold-drawing, whose shape increases the adhesion (Tor, Caron) appear to be of interest: Isteg is of less value owing to its rather low apparent modulus of elasticity and its rather bulky shape. In any case it is necessary to go cautiously with high resistance steels and not exceed 20 kg/mm² (12.70 t per sq. in.) taking into account all the loads (including temperature and shrinkage), even if the quality of the steel makes it possible to do so in theory. In our opinion it would even be preferable to lower the limit to 17 or 18 kg/mm² (10.79 or 11.43 tons per sq. in.) in Railway bridges which are submitted to vibrations which increase the danger of cracks forming. The real tension stresses in the concrete should be calculated, and a reasonable limit fixed.

S. N. C. F.
(Freyssinet type for 250 t)



Denmark.

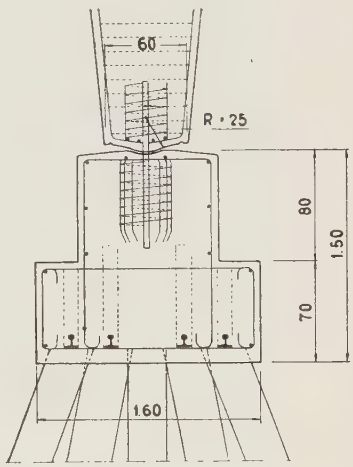


Fig. 55. — Articulated joints in ferro-concrete.

Satisfactory reinforcement is as fine and close together as possible, whilst leaving room to use good quality concrete of a suitable consistency. The reinforcements should not be heaped up but well spread out. Crossing reinforcements should be rigid and held fast, so that they will not get out of shape when the concrete is poured in; the stops used to maintain the correct distance between the outer bars and the framing must be sufficient in number and well fixed.

The *supports* of full plates consist of

rails or flat bars. In this case shrinkage is more dangerous than in the case of concreted joists; provision is therefore made for slipping even on short spans (6 to 8 m); France provides rollers as soon as there is 20 m of expandable length. Girder bridges are fitted with roller supports as soon as the span exceeds a certain figure, varying from 12 m in Denmark to 20 m in France and 25 m in Holland. Only the S. N. C. F. has made measurements to ascertain the coefficient of friction of the supports, in correlation with the research work mentioned in part *a* (see page 1671/81); it was found to be 1 % for roller supports.

Articulations should be avoided as far as possible, as they form difficult points which it is hard to inspect and are the cause of vibrations. France and Denmark suggest reinforced concrete articulations, which they have found satisfactory (fig. 55).

The regulations concerning the depth of *ballast, protective cappings* and drainage are the same as in the case of encased joists (see page 1690/100).

So far only the S. N.C. F. has experimented with *track laid directly on concrete*, a method from which much is expected, dealt with in part *a* (metal Railway bridges with reinforced concrete casing (see pages 1674/84 and 1675/85).

Railway bridges with *prefabricated components* are rare. The only example is the Etaples Viaduct (France) where in order to save scaffolding and framing, the beams replacing the part that was bombed in 1944 were prefabricated, connecting irons being provided for the connection of stays and upper decking. Constructions of this kind involve the use of joints and articulations which rob concrete of one of its essential features : its monolithic character. The prefabrication of small slab bridges is more interesting, as this would enable the quality to be improved without any corresponding disadvantages other than the difficulty of transport and erection.

Summaries for part b).

There are some reinforced concrete Railway bridges more than 50 years old. The systematic use of reinforced concrete is however only 10 to 20 years old according to the country. It is however already possible to get an idea of how it will stand up in service. The results are convincing : reinforced concrete is suitable for the construction of Railway bridges. The experience acquired, the progress made both as regards the quality and use of the materials and in the design of the bridges, only serve to strengthen this opinion.

The most favourable use for bridges is the full slab up to a span of 12 to 15 m, and in wide or strongly surbased arches. The straight beam requires a certain circumspection, as there is a greater risk of cracks; the caisson beam is better than the *T* girder; in the case of continuous beams it is possible to reduce the oblique tension stresses by a careful study of the moment of inertia.

The calculations should take into account the fact that reinforced concrete bridges have a monolithic character. The concrete should be of good quality with a high resistance to tension; the reinforcement should be fine and close together, and distributed over all the parts when there is any tension. Amongst the high tensile steels the choice should fall on those offering the best adhesion.

Joints and articulations break up the monolithic character of the concrete; they should therefore be avoided. The same applies to prefabricated components.

It would be desirable to undertake systematic tests to ascertain the dynamic stresses.

***

c) The future of prestressed concrete.

The introduction of prestressed concrete, new and vigourous technique, goes back to about 1928, if we forget the earlier hesitant experiments which proved unsuc-

cessful. The great originator of this method is M. FREYSSINET, who attracted the attention of the whole world in 1934 with the famous Gare Maritime at Le Havre: but the first industrial applications of the method only go back to the last war and immediate post-war period; they are still few and bar between and it is premature to take the experience obtained as final. It is presumptions to try and foretell the future of this technique, which is full of promise but still in its infancy. We will limit ourselves therefore to reporting the facts in so far as they concern the Railway field, and trying to draw certain conclusions from them, but these must of necessity be provisional and the future may contradict them.

France is the « cradle of prestressed concrete », but curious to state the C. F. F. are the only system of the group to mention prestressed concrete *Railway bridges* (See plate 24); they report 22, all small bridges, due to the shortage of steel during and immediately after the war; on two of them, of 11 and 12 m span respectively, the FREYSSINET method was used; the beams, which are more or less of rectangular section (see fig. 56) are contiguous and their solidarity has been assured by transversal prestressing and an upper decking of ordinary reinforced concrete. The 20 other bridges, with spans ranging from 2.40 to 10.50 m are of the « adhesive wires » type and with one exception belong to the mixed type of bridge (small girders of I section or flexible elements).

Fig. 56. — *Swiss Federal Railways :* Zwingen bridge; span : 39 ft. (right : girder of road bridge).

The S. N. C. F. on the other hand mention several *road bridges*. In 1934 they built a 1.50 m wide bridge with two distinct spans of 31.64 and 30.11 m there are two lateral girders acting as hand-rails, prestressed by the FREYSSINET process and put into position by crane; decking and connecting

Fig. 57. — *Swiss Federal Railways :* Gallery for protection against avalanches.

Fig. 58. — *Netherlands Railways :* Yoke for the catenary.

stays in ordinary concrete done on the site. In 1948 another bridge, similar in design but with four separate spans of 35.50 m and 3 × 32.70 m; 3 m wide. The S.N.C.F. has recently undertaken the construction of some more important bridges (see plate 25); Mont-de-Terre road bridge at Fives : span up to 30 m; width 12 m; the part on the Hellemes side is a cantilever bridge, the central beam being 28.45 m long; Freyssinet method beams; joined up by transversal prestressing carried out on site.

Toulouse-Matabiau bridge : 3 spans of 16.45, 21.60 and 14.85 m; 28 m wide. Freyssinet method. This is a cantilever bridge as regards the dead weight; longitudinal supplementary prestressing gives continuity under the live loads. The S. N. C. F. mentions certain difficulties in carrying out the work. Rouen covered gallery : 1 800 m long, span 8 to 18 m. Example of the superpositioning and assembling of prefabricated, prestressed components (see *Travaux*, January 1949).

The C. F. F. have a road bridge of 12 to 16 m span, 16 m wide; six Freyssinet type beams 1.45 m high, connected by cross stays and upper decking of ordinary concrete.

Other structures in prestressed concrete mentioned by France include the catenary posts (Weinberg system - S. N. C. F.) and the lamp-posts (S. N. C. F. system - Vallette-Weinberg); the C. F. F. have built a protective wall against avalanches (fig. 57) formed of beams with adhesive wires, and catenary posts (adhesive wires or Freyssinet fixing); Holland has catenary yokes (fig. 58). The S. N. C. B. is proposing to investigate the possibilities of prestressed concrete for road bridges and roofs. We are leaving aside the question of Railway sleepers, as this question was dealt with at the 1947 Lucerne Congress and in 1949 at Lisbon during the Meeting of the Permanent Commission (see reports by MM. LEDUC, TRAIN and GONON).

There are two ways of *fixing the wires* in the concrete : the terminal type (Freyssinet method) or simple adhesion (Hoyer method). Many investigators have suggested variations of these methods.

With terminal fixing, it is possible to regulate the prestressed tension of each wire and make good any possible slip. Subsequent slipping is less likely to occur. It is better when curved bars are used — the question of friction still remains to be solved — and makes it possible to use thicker wires, being independent of the limit of adhesion. The additional tension to be given to the reinforcement to balance the curve of the concrete is smaller, as the elastic shortening does not come into the picture. It is also possible to eliminate shrinkage to some extent and reduce the importance of contraction by waiting long enough before prestressing. It should also be noted that this is the only method which can be used on site.

It is very important however to ensure that the wires are well covered; this is essential for the conservation of the work and cannot but improve the binding in and decrease the likelihood of cracks. The outer covering must therefore be injected. The C. F. F. have had some trouble with masts of this type, because the injecting had not been properly carried out; water got into the covering and frost caused longitudinal cracks.

Liaison by simple adhesion is of interest when components have to be mass produced and the necessary plant fitted up. The process can be particularly recommended in the case of short parts : in such cases terminal fixing, in terms of the number of wires and not of their length, is proportionally very expensive; in addition it does away with the loss of stress due to the small amount of slip which inevitably occurs when the cones are locked, which is unimportant in the case of long wires but becomes relatively large in the case of short parts. The diameter of the wires is limited by the adhesion stresses (max. 2 mm for smooth wires, 5 to 6 mm for those with increased adhesion). Although the Railway bridges built in Switzerland by this method do not call for any comment, care

should be taken in using the method on structures submitted to shocks until the effects of the dynamic stresses are better known.

The ideal prestressed construction would be that in which, owing to the play of the prestresses, all tension effects due to no matter what loads and in no matter what direction are eliminated. Only in such a case would it be possible to use to the full the resources of the method and materials. It will be seen that present realisations fall into *two types of structures:*

1) those approximating more or less to this idea : pylons, isolated beams, practically monoaxial systems; bridges with adjacent joists pretressed transversally on site; bridges with separate beams, joined crosswise by prestressed stays and by a decking which only carries compression stresses;

2) mixed structures where there are large areas of ordinary concrete working under tension. This is the case with small I-type beams with concrete used as a filling as in the case of bridges with encased metal joists and prestressed elements of greater or lesser flexibility acting as the reinforcement of a section in ordinary reinforced concrete. These are not really prestressed structures, but structures including prestressed elements. Does stretched concrete crack, and what are the effects of such cracks on adjacent prestressed elements? What are the effects of flow (« fluage ») and shrinkage on the faces in contact of these concretes of different quality and age? All these questions are still unsolved. This technique was born of wartime needs, when steel was in short supply; we do not think it will be widely used once the steel position returns to normal. Small « I » girders in prestressed concrete in addition to the hazards already mentioned, are more difficult to put into position than DIN girders; they are also higher, lacking in straightness, and complicate the transversal reinforcements. The system using flexible elements has no advantages over ordinary reinforced concrete; the taking up of the oblique tension stresses is a very difficult matter.

In our opinion, the future lies with real prestressed structures rather than with these mixed types. As for deciding whether it is preferable to carry out the prestressing in the factory or on site, this depends on circumstances. Prestressing in the shop is advantageous in the case of single parts of the « beam » type, i.e. of an essentially monoaxial character, mass produced; the quality is bound to be better. But, as the S. N. C. F. points out « bridges are generally individual structures, and rarely justify the installation of a real shop at a reasonable distance from the place of work, so that it is necessary to carry out the work on site ». Moreover the parts will utimately have to be put under tension on site; as far as the following operations are concerned : assemblies, continuity joints, prestressing in other directions, operations which, let us repeat, must be done if a true pretressed structure is to be obtained.

Sometimes ordinary reinforcements have been added to the prestressed reinforcements. Although it is quite plausible to make use of local reinforcements in mild steel (straps, bindings of the fastenings, special bars to prevent cracks during transport or before being prestressed), we cannot agree in general with the *combination of reinforcements* in which part of the tension stresses which are not taken up by the prestressed reinforcements are passed on to the ordinary reinforcements; ordinary reinforced concrete and prestressed concrete differ too widely in their structure. Nor should it be forgotten that all tests carried to cracking point on prestressed samples showed that the cracks closed up again when the press was removed; if any slip occurs, an ordinary reinforcement might prevent the cracks closing up. Consequently such a combination of reinforcements should not be considered except in special cases.

The effects of *repeated loads (fatigue effects)* do not appear to be dangerous, as variations in stress in the steel remain at low values compared with the permanent tension (which moreover makes it possible

to work very close to the limit of elasticity). There is general agreement on this point. It may however be necessary one day to take into account the resistance of the concrete to repeated stresses if its quality is modified in order to take into account much higher rates of working; from this point of view concrete is in rather an unfavourable position, since by construction, we sweep away with the live loads the whole field of utilisation of the resistance to compression, from zero to the maximum allowed.

The hysteresis of steel also raises a problem. The qualities used have not got a definite level of deformation; the « limit of elasticity » is defined conventionally as the stress for which the permanent deformation is ~ 0.2 %. Although this limit is often raised by the excess pressure given to the steel, it may happen that at times we are still working in a zone where the deformations are not strictly proportional to the stresses. Even if the variation in the stress is small compared with the permanent stress, this point must be elucidated before bridges with a very high frequency of load are made of prestressed concrete.

It is not very likely that the *dynamic effects* are higher than in the case of reinforced concrete bridges; but experience on this point is lacking. The S. N. C. F. and the C. F. F. have used the standard formulae to calculate the various elements for their bridges. As for ascertaining if these effects are dangerous, it is too early to say. The S. N. C. F. estimate that « they are less harmful in the case of the prestressed concrete elements (taken separately) of a bridge than in the case of similar elements in ordinary reinforced concrete, as in this case we are dealing with an elastic material which is less likely to crack ». But « these actions are dangerous on the prestressed structure as a whole (especially in the case of a bridge) when its monolithic character is of a certain importance as regards the ultimate behaviour of the work in question. It is to be feared that in time the assemblies of the different elements will slacken under the vibrations caused by the live loads ». The C. F. F. recommend « avoiding violent shocks (rail joints for example) which might damage the tension or fixing of the wires ».

The *working rate of prestressed concrete* is generally 100 to 120 kg/cm² (1 422 to 1 706 lbs. per sq. in.); it is dependent on the quality of concrete obtainable and is very like that of ordinary reinforced concrete. A reasonable increase in the allowable stresses — together with an improvement in the special steels used — would be much more useful in the case of prestressed concrete than in the case of ordinary reinforced concrete where cracks are always a stumbling block. Present technical and economic conditions are such that if prestressed concrete is a competitor in the case of structures with a low live load, it is far from being so in the case of Railway bridges; this is due to the fact that the dimensions of a prestressed girder vary in almost direct proportion to the live load, the prestressing being so regulated that it counteracts the effects of the dead weight. Improved resistance will doubtless go hand in hand with increased rigidity of the concrete, which will diminish the relaxations.

The *steels* used so far are of the machine wire type (S. N. C. F.) with 90 kg/mm² (57.14 t per sq. in.) breaking strength R and 80 kg/mm² (50.79 t per sq. in.) elastic limit L or wiredrawn steel (France, Switzerland) R = 140 to 170 kg/mm² (88.89 to 107.90 t per sq. in.); L = 110 to 130 kg/mm² (69.84 to 82.54 t per sq. in.). It would obviously be of value to improve their qualities still further, especially their elongation.

It has sometimes been stated that prestressing will make it possible to do away with *watertight cappings.* Although prestressing does away with cracks, one of the reasons why concrete is not watertight, it does not correct the porosity of the concrete to the same extent, and this must be overcome by other means if such devices are to be given up. It must not be forgot-

ten also that prestressed works often include elements or assemblies of ordinary reinforced concrete, which make such precautions essential.

Concrete can be prestressed in other ways than by putting the reinforcements under tension; for example large arches are put under tension by means of jacks and the slabs of mixed decks are prestressed by altering the level of the supports (see part *a*, p. 1670/80). There is moreover nothing to prevent other materials than concrete being prestressed; although no application has yet been reported — apart from metal bridges reinforced by under-tension bars acting on the suspension stays — it is only to be expected that the possibility thus given of regulating at will the elasticity will extend the field of use of many materials : stone, plastics, etc.

Summaries for part c.

Prestressed concrete is of undoubted interest, but must not be considered as a special kind or extension of reinforced concrete. It is a new material, which has its own characteristics and consequently field of use. Its essential advantages lie in the fact that there are no cracks and, for equal quality and strength, a prestressed concrete beam is smaller in height than an ordinary reinforced concrete beam.

In the present state of the technique, prestressed concrete already lends itself to the mass production of parts : posts, pipes, framework or roofing components, and, naturally, sleepers. It is also of interest in the case of reservoirs, without mentioning other works which do not directly concern the Railway, such as aeroplane runways, harbour works, etc.

In the case of bridges, the advantages are not so marked. The process may well be used in the case of certain over bridges, but if full use is to be made of its characteristics, it must have to stand up to much higher stresses, which implies the use of very high grades of concrete; there are also certain points to be cleared up : behaviour as time goes on, relaxation, hysteresis of the steels, effects of shocks. The technique of preparing it has still to be perfected, as regards assemblies in particular.

When used with full knowledge of its characteristics and to the maximum of its resources, prestressed concrete can be used as a complement to ordinary reinforced concrete, especially in the case of straight beams where ordinary concrete is not satisfactory. These must be of prestressed concrete throughout, and not of a mixed system with stretched concrete in some parts, or assemblies in which the connections, which are not prestressed, take away one of the main advantages of reinforced concrete : its monolithic character. Partial prestressing is of little value except in the form of local prestressing making it possible to modify the safety factor of the work as a whole.

To sum up.

Although the number of replies on which our report is based are few, we hope that it has nonetheless achieved its object : to collect together the experience and conclusions of the specialists of the different Railways, and to make known the practical interpretation given to these observations.

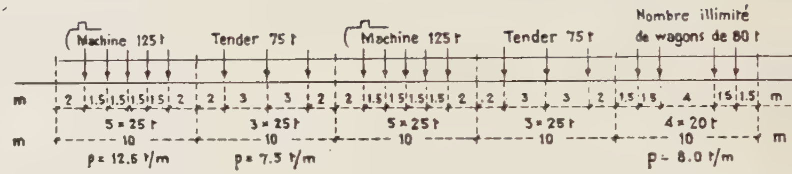
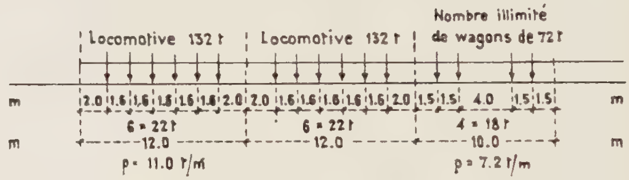
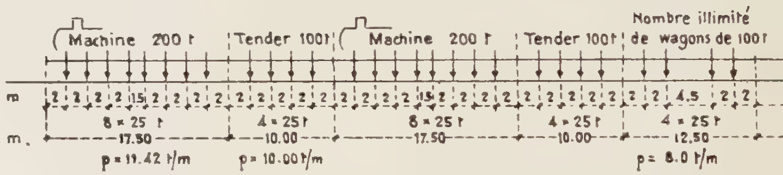
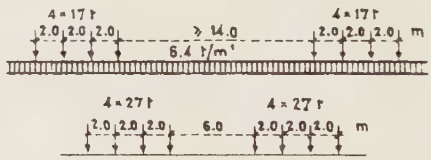
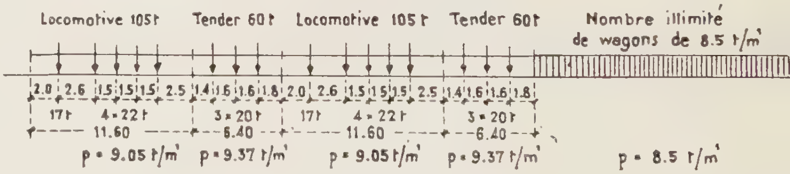
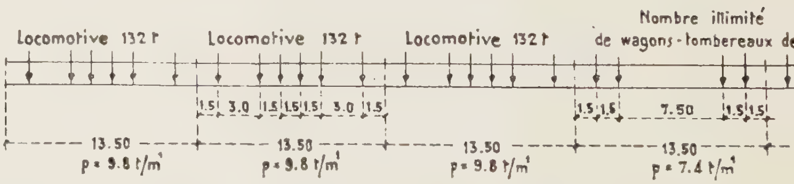
The methods at the disposal of builders are being multiplied : they are mutually helpful and complementary. Competition between different materials, which is often mentioned, is rather artificial; if the *facts* of a problem are fully known, it is rare for a solution to remain undiscovered.

Our summaries have still to be compared with those of Professor POLSONI (Rome) for the second group of French speaking countries and those of M. A. DEAN (London) for the English speaking countries. As far as we are concerned, we would like to stress the remarkable unity of opinion regarding the conception of bridges. At a time when the Arts have become so nationalised, it is

exhilirating to see that the Art of Building knows no frontiers.

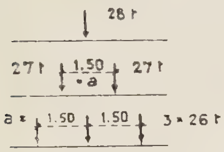
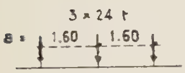
This unity of opinon is not based on uniformity, since it does not exclude either variety in detail or original ideas; nor does it prevent new solutions being sought; it is simply the manifestation of the progress made in the search for truth.

PLATE 1. — **Live l**

Country	Type train
BELGIUM	
DENMARK	
FRANCE	
NETHERLANDS	
NORWAY	
SWITZERLAND	

Note. — Nombre illimité de wagons = Unlimited number of wagons. — Machine = engine.

ain-line railway bridges.

Special groups	Max. axle loading	$\frac{p}{a}$ max. for set of 2 axles	$\frac{p}{a}$ max. for set of 3 axles
	isolé : 28 t double : 27 t triple : 26 t	$\frac{27}{1.50} = 18.0$ t/m¹	$\frac{26}{1.50} = 17.3$ t/m¹
	24 t	$\frac{24}{1.60} = 15.0$ t/m¹	$\frac{24}{1.60} = 15.0$ t/m¹
——	25 t	$\frac{25}{1.50} = 16.7$ t/m¹	$\frac{25}{\sim 1.75} = 14.3$ t/m¹
	27 t	$\frac{17}{2.00} + 6.4 = 14.9$ t/m¹	$\frac{17}{2.00} + 6.4 = 14.9$ t/m¹
——	22 t	$\frac{22}{1.50} = 14.7$ t/m¹	$\frac{22}{1.50} = 14.7$ t/m¹
——	25 t	$\frac{25}{1.50} = 16.7$ t/m¹	$\frac{22}{1.50} = 14.7$ t/m¹

Country	Coefficient of increased allowance for dynamic effects (L = span in m.) — metal bridges		reinforced concrete masonr
Belgium	track on metal rail joints	$1.20 + \frac{17}{L + 28}$	light joists in concrete casing:
	track on metal without joints track on wood with joints	$1.19 + \frac{21}{L + 46}$	reinforced concrete : 1.25
	track on wood without joints track on ballast, with joints	$1.11 + \frac{56}{L + 144}$	heavy arches : 0
	track on ballast, without joints	$1.00 + \frac{60}{L + 150}$	
Denmark	track on sleepers with rail joints	$1.00 + \frac{48}{L + 60}$	
	track on sleepers without joints track on ballast with joints	$1.00 + \frac{40}{L + 60}$	as for metal bridges
	track on ballast without joints	$1.00 + \frac{32}{L + 60}$	
France	all bridges : $1.00 + \frac{2}{L + 5} + \frac{0.6}{1 + 4\frac{P}{S}}$ P = total permanent loads, S = max. weight of live loads — on the part in question		
Holland	track supported directly on girders	$1.00 + \frac{60}{L + 100}$	$1.00 + \frac{60 - \frac{1}{2} D}{5 L + 100}$
	bridges without ballast	$1.00 + \frac{50}{L + 100}$	
	bridges with ballast	$1.00 + \frac{40}{L + 100}$	D = depth of ballas below sleeper
Norway	$1.00 + \frac{17.65}{L + 20}$ (L = length under load)		concrete light girders : — as for metal bridges reinforced concrete : — according to German or Swedish standards arches : variable
Switzerland	steam traction : $1.00 + \frac{11 + 0.1 \cdot L}{L + 10}$ electric traction : $1.00 + 0.75 \left(\frac{11 + 0.1 \cdot L}{L + 10}\right)$ reduction for elimination of rail joints : 10 % reduction for bedding on ballast : 10 %		

y bridges.

Wind loading		Temperature variations with respect to temp. at erection		Friction	Friction at supports (fraction of reaction R)
loaded dges	non overload. bridges	Metal bridges	reinforced concrete		
/m^2	kg/m^2				
50	250	± 30°	—	1/7 of the overload	
50	250	± 35°	— 15° + 15°	1/7 of the overload L_{max} = 100 m	rollers : 0.03 slide bars : 0.30
50	250	± 27°	± 20°	1/7 of the overload (max.of overl. = 2 000 t)	
50	—	± 35°	+ 10° — 20°	1/7 of the overload (special group for axles limited to 20 t).	rollers : 0.03 slide bars : 0.20
50	250	± 40°	—	1/7 of the overload	rollers : 0.03 slide bars : 0.20
00	150	± 30°	± 20°	1/7 of the overload	rollers : 60 $\frac{R}{H.d}$ R in t/cm^2 H Brinell kg/cm^2 d = diam. in cm slides : 0.20

PLATE 3. — **Equivalent loads per m and maximum moments in m per t.**

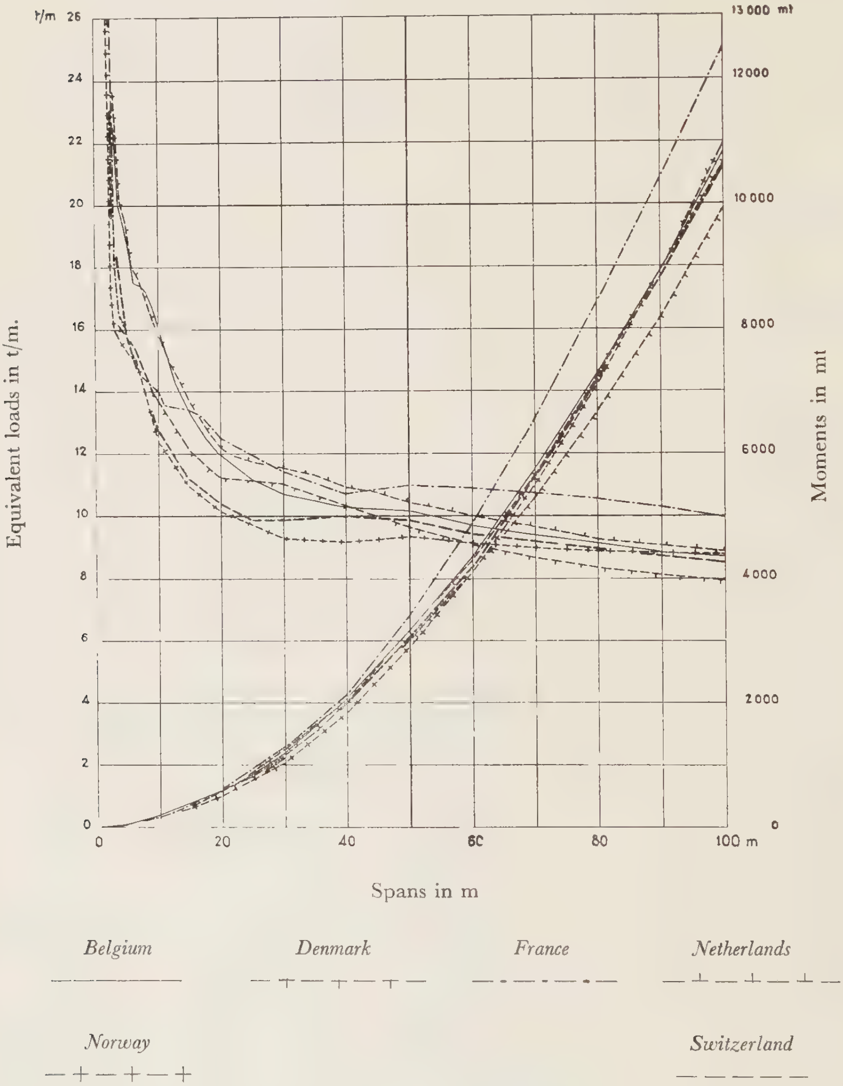
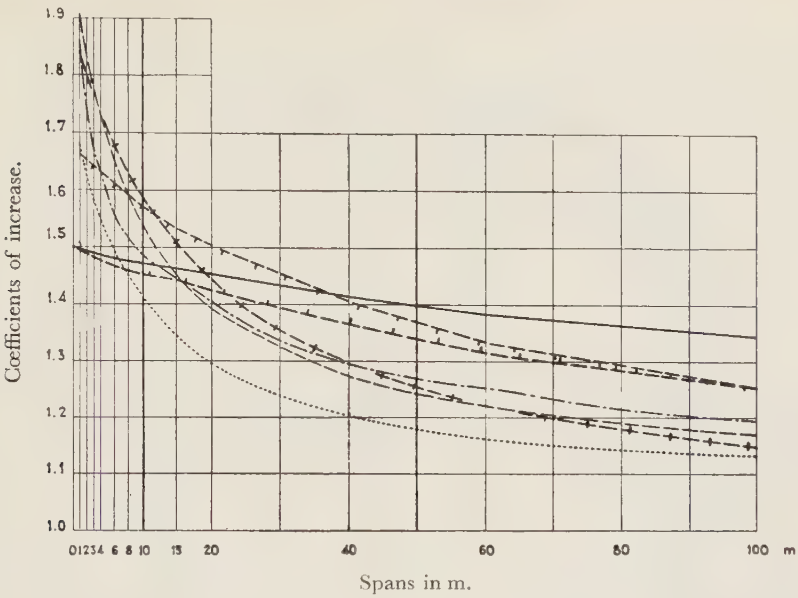


PLATE 4. — **Coefficients of increased allowance for dynamic effects.** — 1. **Metal railway bridges.**
(Track on sleepers without rail-joints.)



Belgium ———————

Denmark — ┬ — ┬ —

France — - — - — - —

Netherlands — ┴ — ┴ —

Norway — + — + — +

Switzerland

Electric traction - - - - - - - - - -

Steam traction — — — — —

2. **Reinforced concrete railway bridges.** (Track on ballast, with rail-joints).

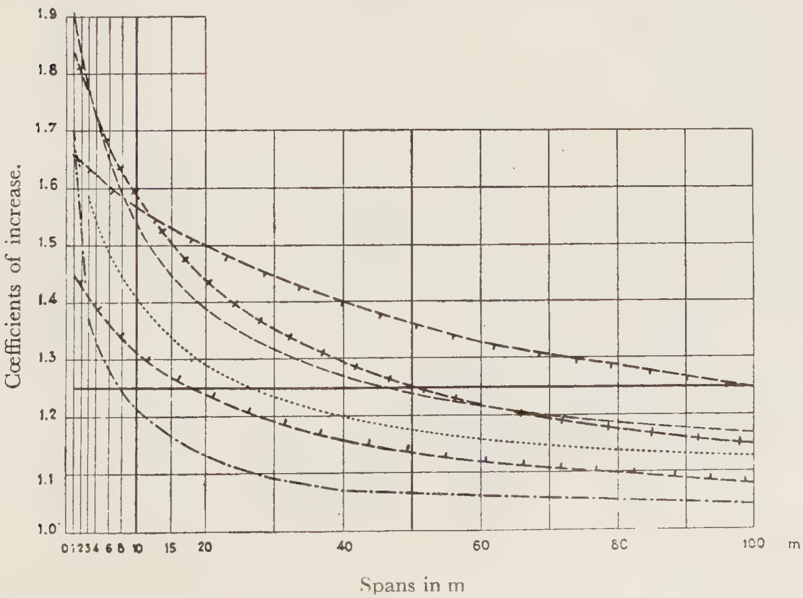
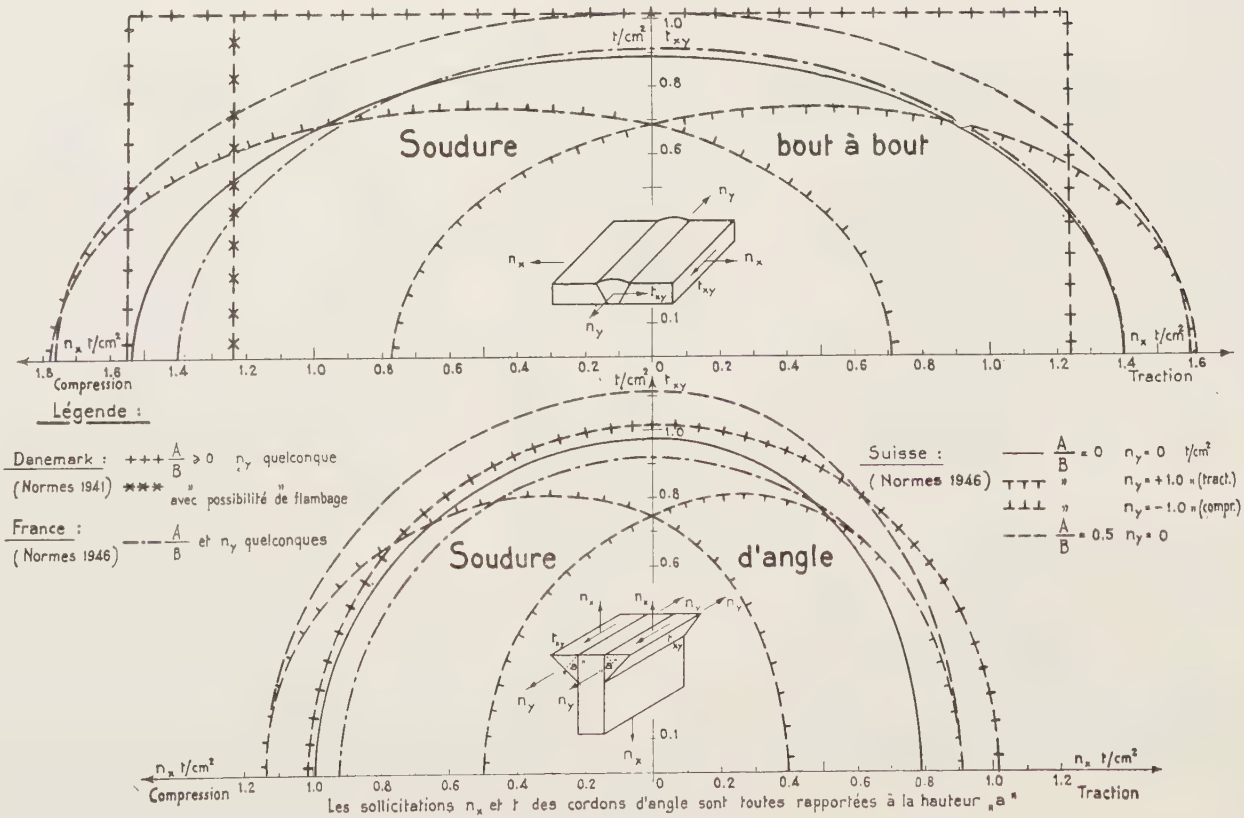


PLATE 5. — **Stress limits in the welded seams.**

(Mild steel. — Inclusive of live loads, wind loading and temperature. — High quality welding.)



Explanation of French terms :

Soudure = Butt weld. — Bout à bout = Butt welds. — Danemark = Denmark. — Normes 1941 = 1941 standards. Avec possibilité de flambage = with possibility of buckling. — Quelconques = any. — Normes 1946 = 1946 standards. Traction = Tension. — Suisse = Switzerland. — Compression = Compressing. — Les sollicitations n_x et t des cordons d'angle sont toutes rapportées à la hauteur « a » = The stresses n_x and t of the fillet welds are all referred to the height « a ».

PLATE 6. — **Attachment of the longitudinal beams to the stays.**
Belgian National Railways.

Section a-a *Section b-b*

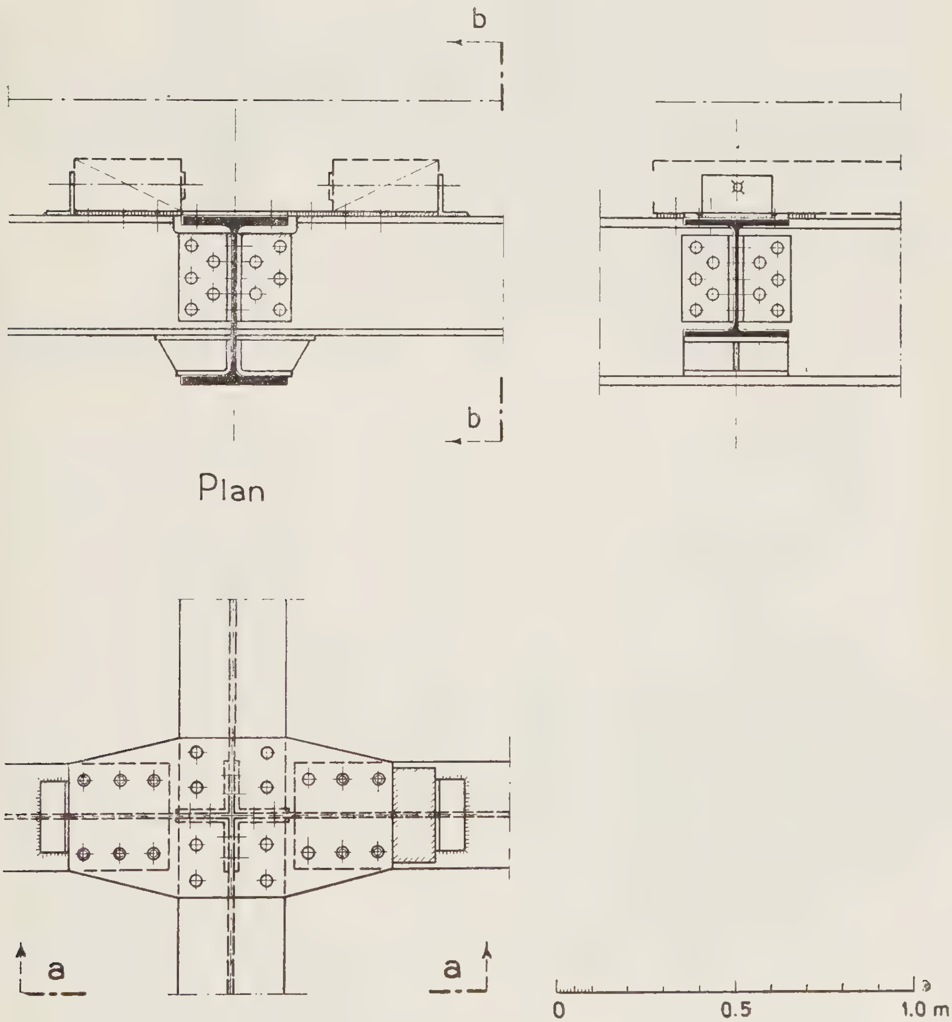
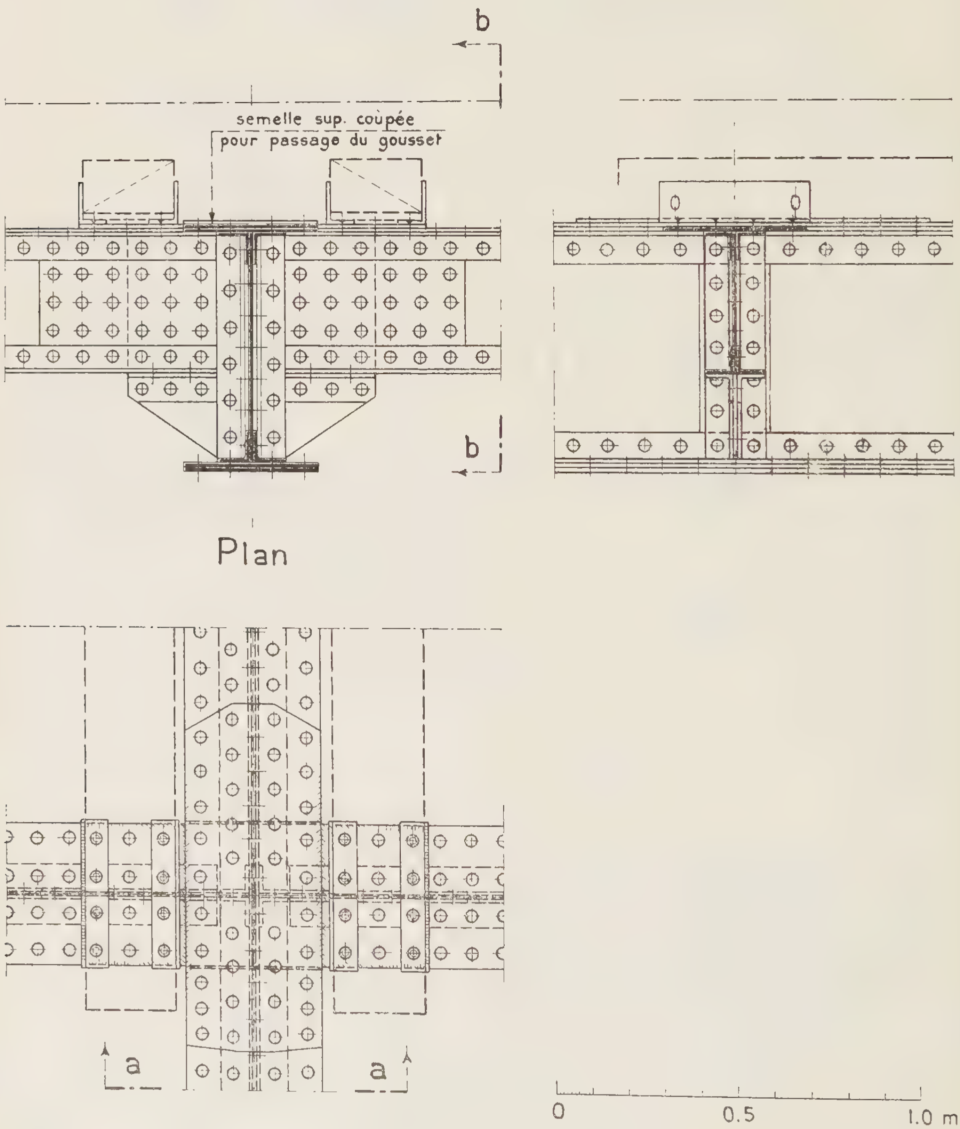


PLATE 7. — **Attachment of the longitudinal beams to the stays.** — *French National Railways.*

Section a-a *Section b-b*



Explanation of French terms :

Semelle sup. coupée pour passage du gousset. = Upper girder flange cut to admit gusset plate.

PLATE 8. — **Attachment of the longitudinal beams to the stays.** — *Netherlands Railways.*

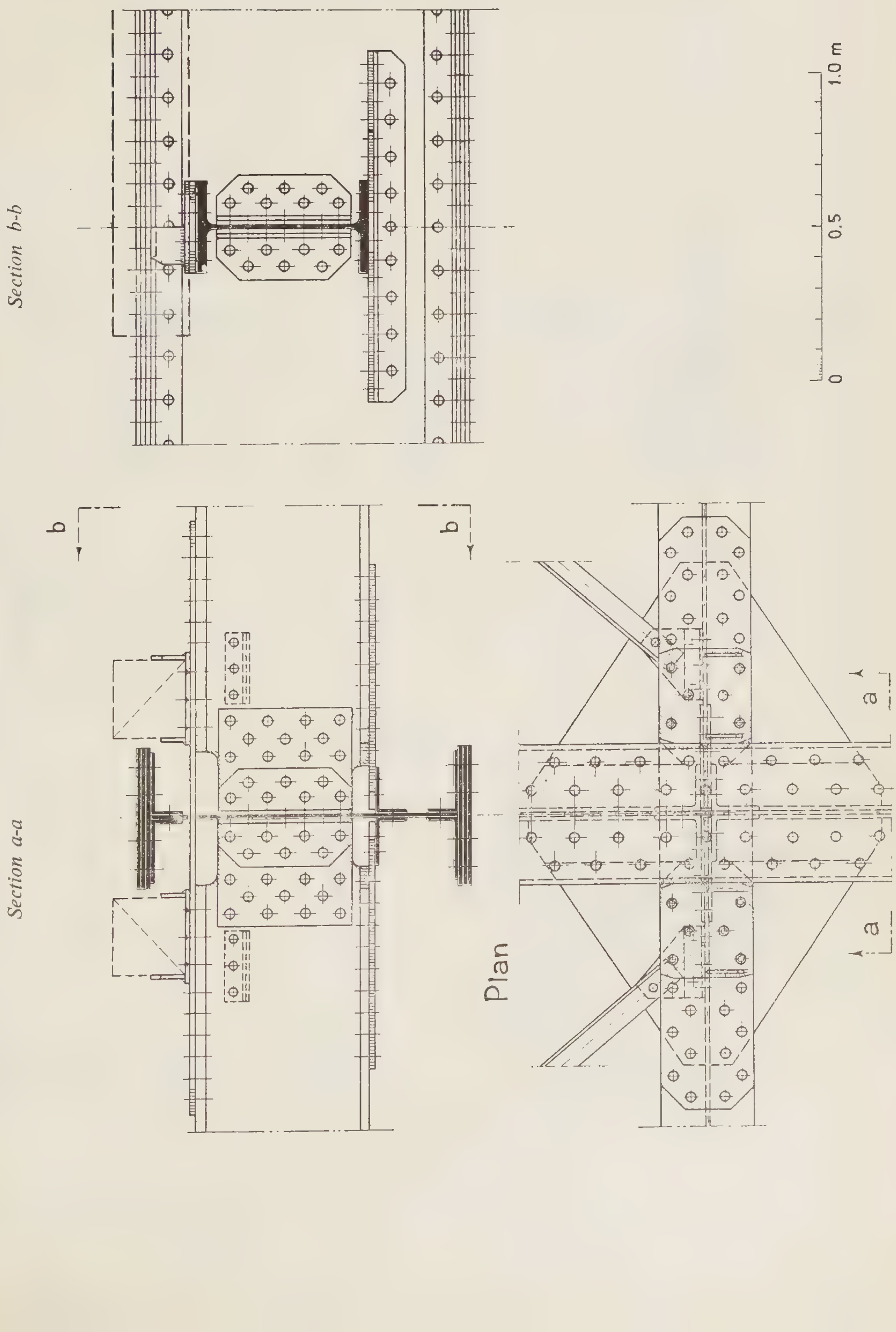
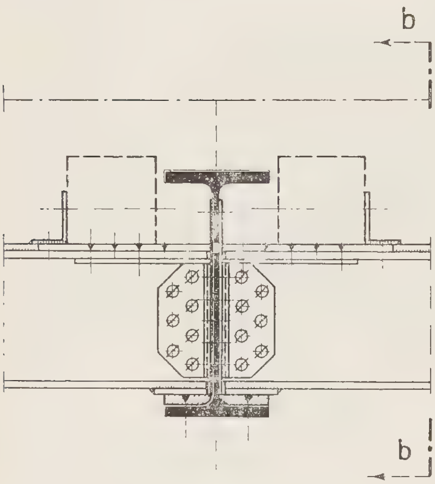
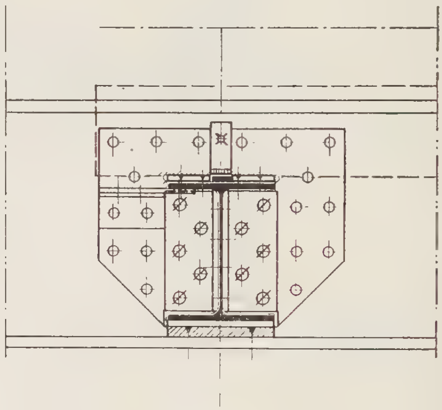


PLATE 9. — **Attachment of longitudinal beams to the stays.** — *Swiss Federal Railways.*

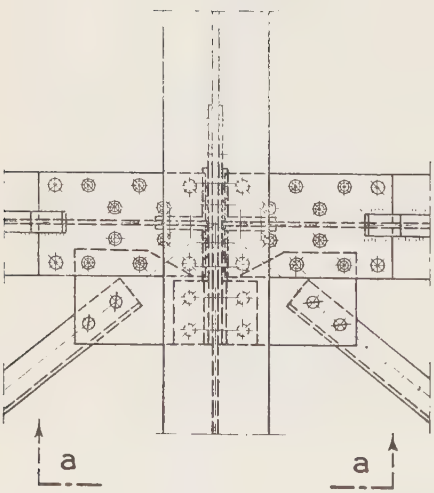
Section a-a



Section b-b



Plan



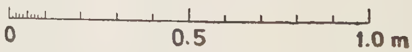
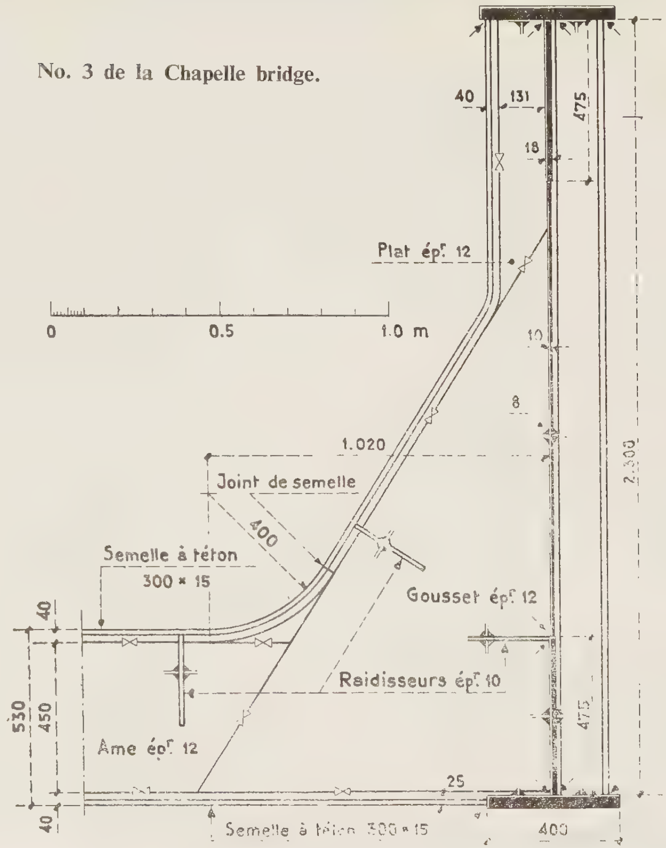


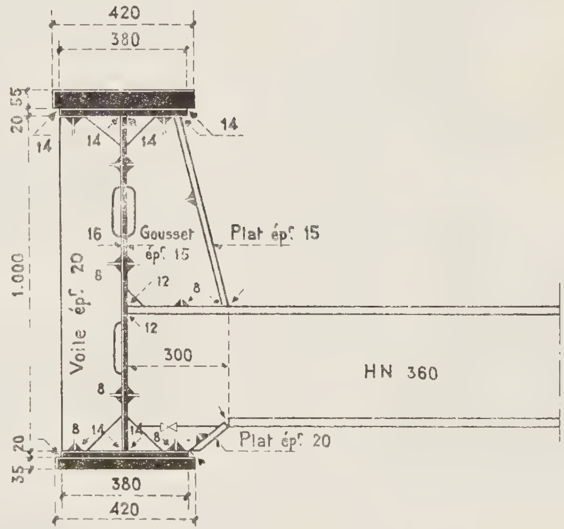
PLATE 10. — **Welded assemblies. — Stays to main girders (France).**

No. 3 de la Chapelle bridge.



Pont de Lille - Sud

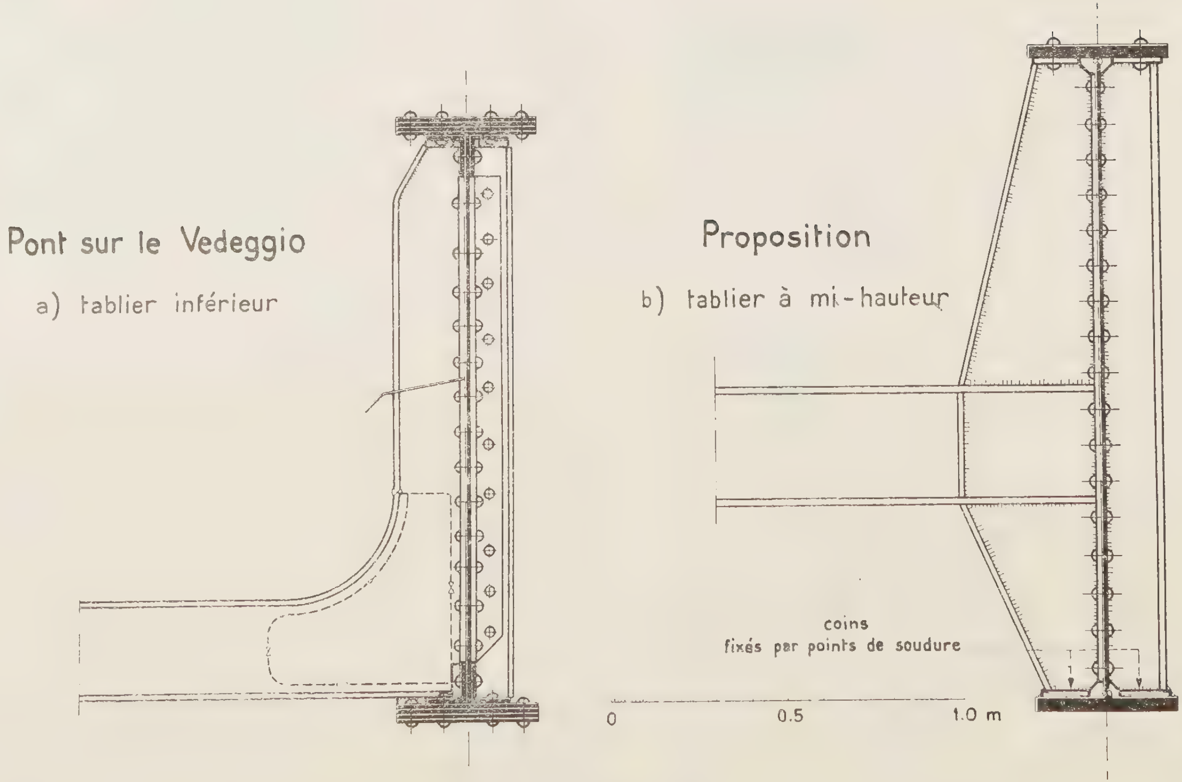
Poutre à béquilles



Explanation of French terms :

Plat ép^r 12 = Thickness of flat plate 12. — Joint de semelle = Plate joint. — Gousset ép^r 12 = Gusset 12 mm thick. — Raidisseurs ép^r 10 = Stiffeners 10 mm thick. — Ame ép^r 12 = Main plate 12 mm thick. — Pont de Lille-Sud = South Lille bridge. — Poutre à béquilles = Girder with struts. — Plat ép^r 15 = Thickness of flat plate 15 mm thick.

PLATE 11. — **Fastening the stays to the main girders (Switzerland).**

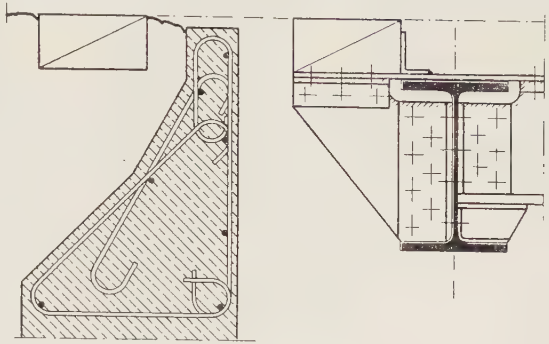


Explanation of French terms :
Pont sur le Vedeggio = Bridge over the Vedeggio. — Tablier inférieur = Low level deck support."—Tablier à mi-hauteur = Deck support at half height of girder. — Coins fixés par points de soudure = Wedges fixed by welded points.

PLATE 12.

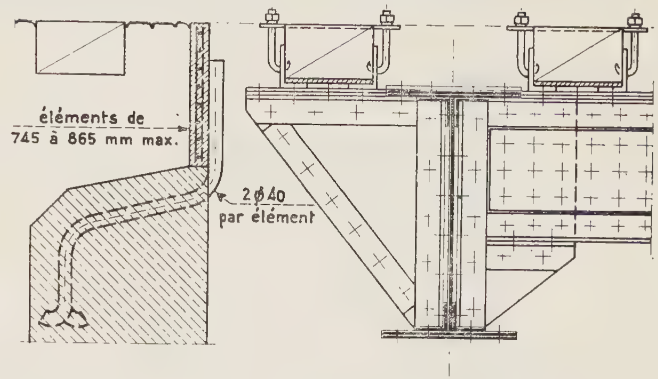
All metal railway bridges.

S. N. C. B. and C. F. F. (Switzerland).

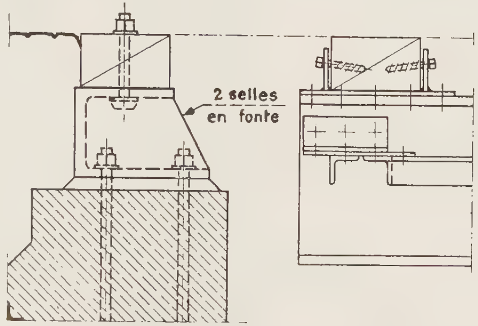


Butt and butt joints for bridge decking.

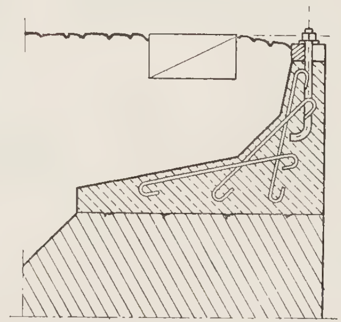
S. N. C. F. (track laid on sleepers).



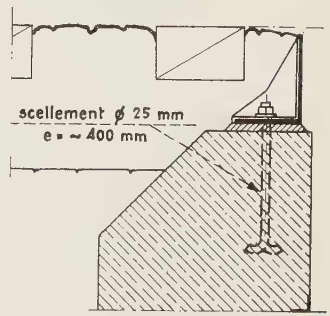
Hollande



Norvège



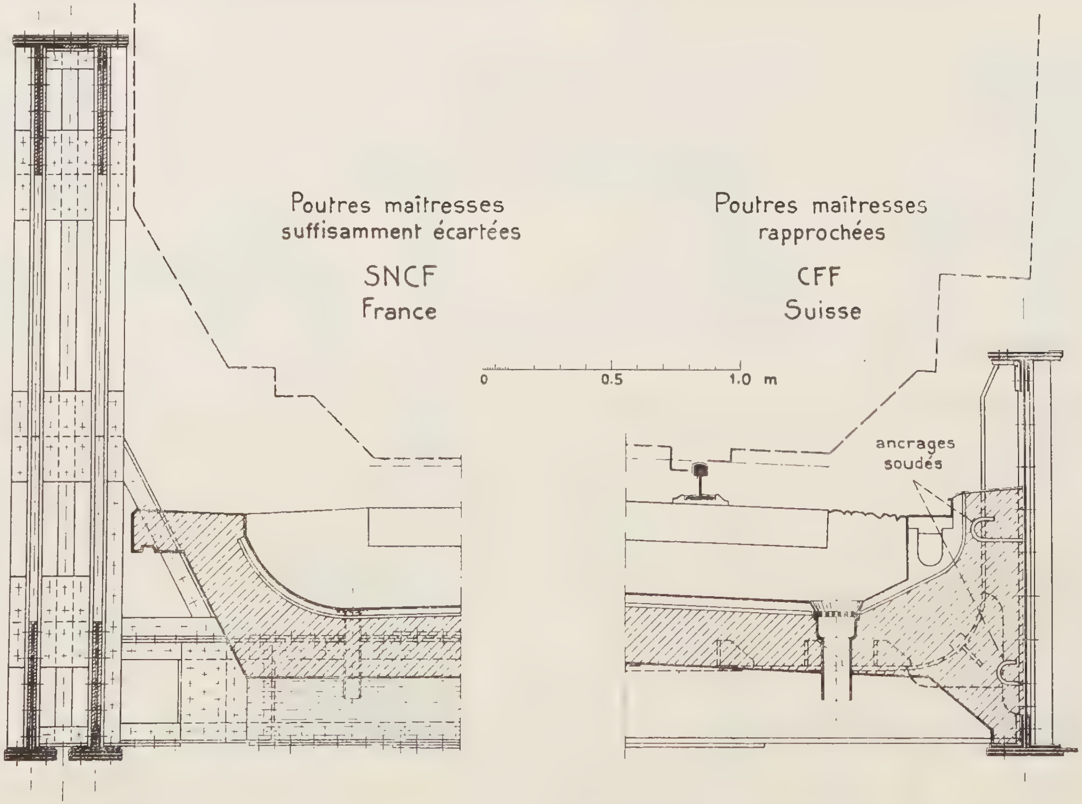
CFF suisses (Variante)



Explanation of French terms :

Hollande = Holland. — 2 selles en fonte = 2 cast iron chairs. — Eléments de 745 à 865 mm max. = Elements of 745 to 865 mm max. — Norvège = Norway. — C. F. F. suisses (variante) = C. F. F. (variant). — scellement ∅ 25 mm e = ∼ 400 mm = sealing ∅ 25 mm e = ∼ 400 mm.

PLATE 13. — **Metal railway bridges covered with reinforced concrete** (Cross sections of bridges with tracks at low level).



Explanation of French terms :
Poutres maîtresses suffisamment écartées = Main girders adequately spaced. — Poutres maîtresses rapprochées = Main girders close together. — C. F. F. Suisse = C. F. F. Switzerland. — Ancrages soudés = Welded anchoring.

PLATE 14. — **Characteristics of concretes for arched railway bridges.**

		Belgium S. N. C. B.	*Denmark*	*France* S. N. C. F. bridges: small and medium	*France* S. N. C. F. bridges: heavy	*Swiss* C. F. F.	*Tunisia*
% cement in kg/m³	arch	250	250	300	Composition decided by individual studies of the granulation.	250	—
	spandrel	200	250	300		coated : 225 not coated : 250	300 to 350
	filling	175	175	—		100	—
Granulation and maximum size of gravel		Sand : 400 *l.* Gravel 10-50 mm : 800 *l.*	d max. ≃ 60 mm 5 mm screening 35-40 % shingle 40-45 % } broken stone	Sand : 400 *l* Gravel : 800 *l* (The gravel may be fairly large in the body of the arches).		d max. ≃ 60 mm Approximate granulation to the curve of the Federal Laboratory : $P = 50\left(\frac{d}{D} + \sqrt{\frac{d}{D}}\right)$ (1)	Good strong concrete
Consistency		—	Slump-test 3-6 cm	—		Moist earth	Slump-test 2-5 cm
Vibration		Not used systematically	—	Induced vibration for bridges of any size.		Induced vibration for loaded parts and for exposed non-loaded parts.	Induced vibration and vibration of the coefficient.

(1) P = % by weight of material (excluding cement) passing a predetermined mesh of screen.

D = max. dia. of aggregates (in this case 60 mm). — d = intermediate arbitrary dia. between 0.1 mm and D.

Classification

Description		Abbreviation	Dimensions		
				Surface of bed	Surface of joi
Cut stones		PT	*Length and height vary*, to be specified in the working drawings *Alternate thickness* about 0.60 to 0.8 m.	Surface trimmed at right angles to half the thickness, approx. for horizontal bedding and on the whole of the thickness for arch stones.	Surface trimme right angles about 0.10 m, remainder thi down or not as case may be.
Small stones squared off		PP	*Free and various.* *Length* : 0.3 to 0.7 *Height* : 0.28, 0.33, 0.38 *Shank* : 0.25 to 0.35	Surfaces trimmed at right angles about 5 cm remainder reduced or	
Rubble	*squared off*	ME et MEV	*Length* 0.25- 0.70 *Height* : 0.18, 0.20, 0,22, 0.24, 0.26 *Shank* : 0.25-0.35	Same treatment as for the small squa off stones.	
	roughly shaped		*Free and various.* *Height* : 0.18-0.40 *Shank average* : 0.30	Surfaces of beds and joints in dressing, without trimming at angles, but without any large pro erance on the faced square.	
	sawn up	MOH MOV MOI	*Free and various.* *Height* : 0.18-0.40 *Shank average* : 0.30	Coarse rubble or ashlar to be dre by the mason.	
	bedded		*Free and various.* *Height* 0.10-0.35 *Shank average* : 0.30	Bedded surfaces to be relatively even parallel, the others : any treatr	
	rough	MO	Any shape.	Rubble without any special treatr having a weight which can be re handled by one man.	

These stones are supplied in 4 qualities : semi-firm (demi-ferme), firm (ferme), hard (dure) and cold (froic which characterize : their resistance to crushing. The choice depends on the importance of the work.

ched bridges.

ibution S. N. C. F.

n Facing ashlaring	Laying	Apportionment
illed for new work. *lit off* (sharpened) for fitting to old work. rface roughened for slopes.	Bedding and joints of 3 cm thickness.	*Only for heavy works* : Noses for piles. — Arch stringers, corner stones.
one *cut* in slabs but retaining traces of round corners, or *split off* or *tapered off*. The 4 edges being kept substantially at right angles to each other.	Bedding and joints of about 3 cm thickness.	*Heavy and medium works* : Bedded rubble. Facing of piles. — Tympans. *Medium works* : String course for arches.
—	— do —	*Heavy and medium works* : *Freing of piles. — Medium works* : String course for arches.
bbed or split off, substantially ectangular.	Bedding and joints of mean thickness 4 cm.	*Medium and small works* : *Freing of piles. — Medium works* : String course for arches.
ce very roughly rectangular, or trapezoidal and having any spect.	Bedding and joints according to shape after the masons have touched up.	*Medium and small works* where rustic design is possible : Facing of piles, abutments, wing wall, etc.
—	Doubtful beds and joints of about 5 cm mean thickness.	*Medium and small works* : Facing of piles, tympans, dowels, arch stringers, walls.
—	—	*General* : Packing, filling, etc., in heavy works, foundations, pile shanks, body of abutments, of tympans, of concealed dressings, facings.

PLATE 16. — **Swiss classification of the masonry work in natural stone.**

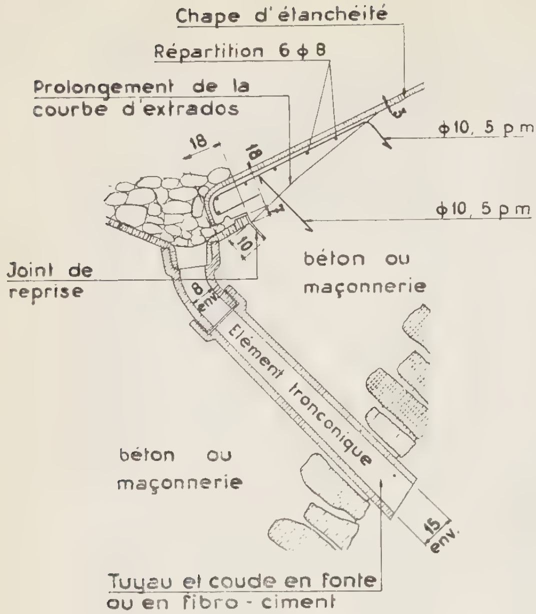
Class	Nature of setting	Treatment of faces of rubble (beds and joints)		Max. thickness of mortar joints	
		for facing	for inside work	normal	exceptional in places
Rubble crude or hammered	Settings irregular or mosaic. Rubble stones more or less regular in size.	Beds and joints $\backsim \perp$ at dressing 10 cm. deep.	—	30 mm	40 mm
Dressed rubble	Settings slightly irregular, height variable, roughly horizontal but made flush every 1 m. Rubble stones to be regular.	Bedding plans on 1/2 surface of setting. Joints squared to 15 cm of depth.	Bedding plans 1/2 surface of setting.	25	35
Spalled rubble	Each setting to be made flush. Difference in height between two consecutive settings = 20 % of the highest. Minimum overlap of vertical joints: 20 cm in dressing, 15 cm in filling.	Bedding plans on 2/3 surface of setting. Joints squared to 25 cm of depth.	Bedding plans on 2/3 surface of setting. Joints on 1/3 surface of joint.	20	25
Cut stone ashlar.	Cutting and laying according to plan.	Dressing according to drawings.	Dressing according to drawings. Beds and joints plans on 9/10 of surface inset.	According to plans normal = 10 mm	—

PLATE 17. — **Utilisation of the classes of masonry applied to natural stone in the construction of railway bridges.**

Distribution by Swiss Federal Railways.

Class	Main body of masonry	Dressing of works in masonry of stone	Dressing of concrete works
Rough rubble or broken by hammer	Foundations, elevation of piles and abutments; tympans and arches save for exceptions noted below.	Piles, abutments and tympans or spandrels in general, soffit for span up to $\sim$ 40 m often with more careful treatment of the faces exposed to view and with greater regularity of the coursed work.	Piles, abutments and spandrels in general, with more careful treatment of the faces exposed to view, greater regularity of the coursed work, and greater penetration of the headers (or bond stones).
Dressed rubble	Medium and large arches with stresses : — at centre of gravity: $15 < \sigma_s < 25$ kg/cm^2 at the groin : $22 < \sigma_r < 37$ kg/cm^2.	String courses and mouldings in general, with more careful treatment. Soffit for span $\lesssim$ 40 m or stresses as for the bulk of the masonry. Piles and spandrels for special work, e. g. in towns.	String courses and mouldings in general with more careful treatment; piles and spandrels for special work, e. g. in the towns.
Spalled stone	Large arches with stresses : — at centre : $25 < \sigma_s < 50$ kg/cm^2. — at the groin : $37 < \sigma_r < 75$ kg/cm^2	String courses and mouldings for large arches, according to stresses as for the bulk of the masonry.	String courses and mouldings for large arches, according to stresses.
Cut stone or ashlar	—	Unusual string courses and mouldings. — Plinths.	Unusual string courses and mouldings. — Plinths.

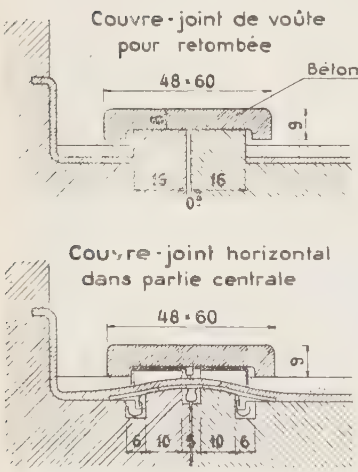
Note. — The above stresses are understood to be for cement mortar masonry and for stones whose strength in resisting crushing of a cube reaches 800 kg/cm^2, if the resistance of the stone is $<$ 800 kg/cm^2, the permissible stresses are proportionately reduced. In certain cases, they may likewise be increased to twice the above value.



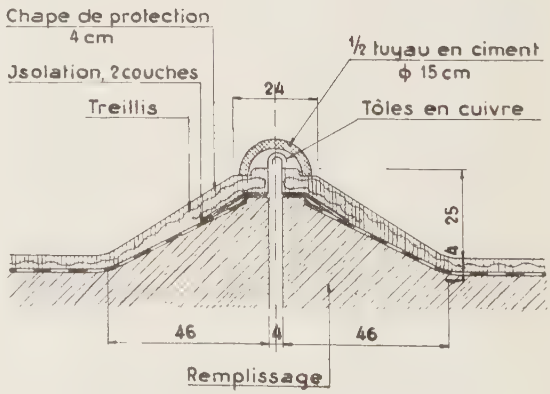
Revers d'eau en béton armé Type S.N.C.F.

Couvre - joint pour ponts exécutés en deux étapes

S.N.C.B.

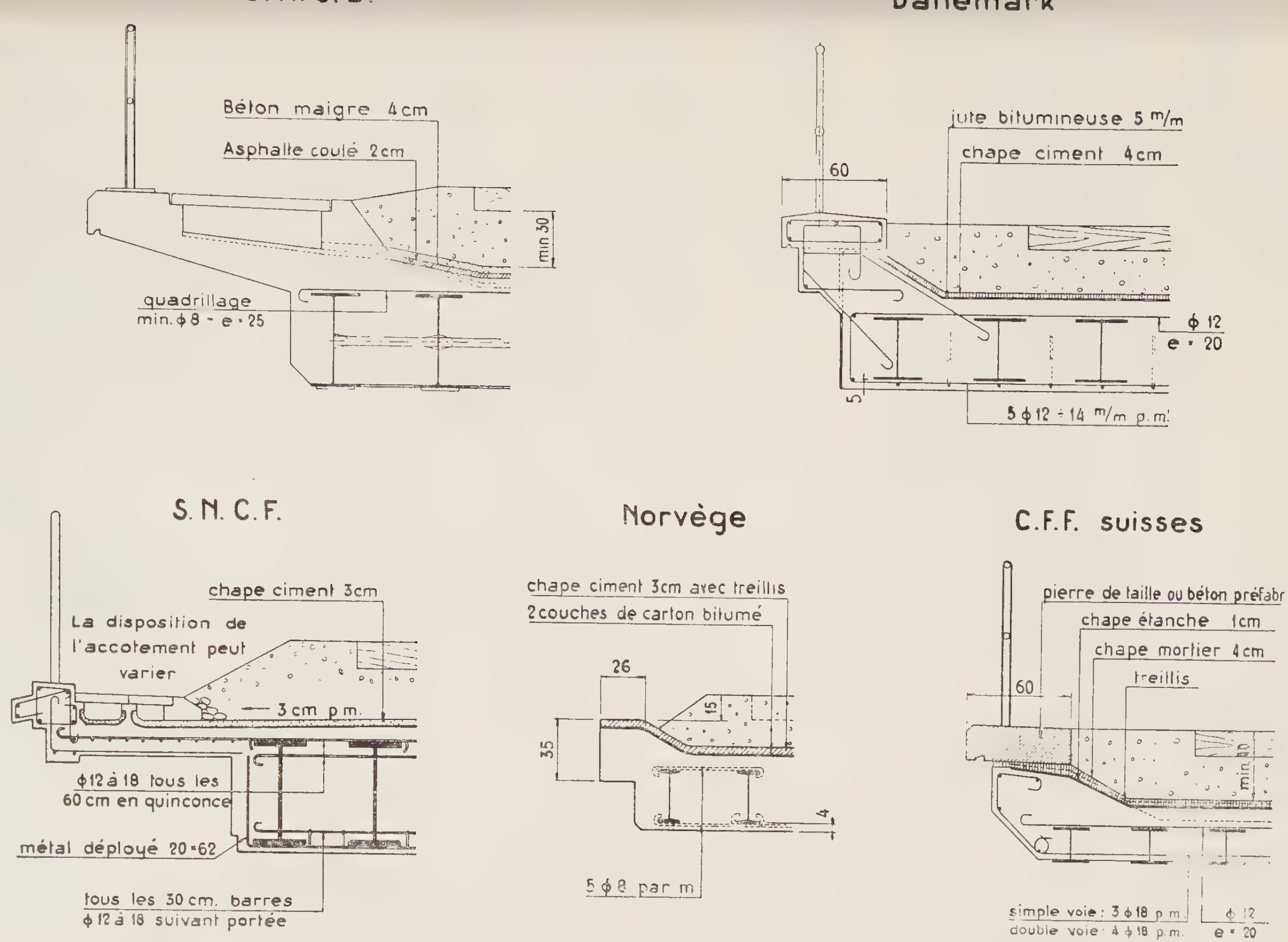


C.F.F. suisses



Explanation of French terms

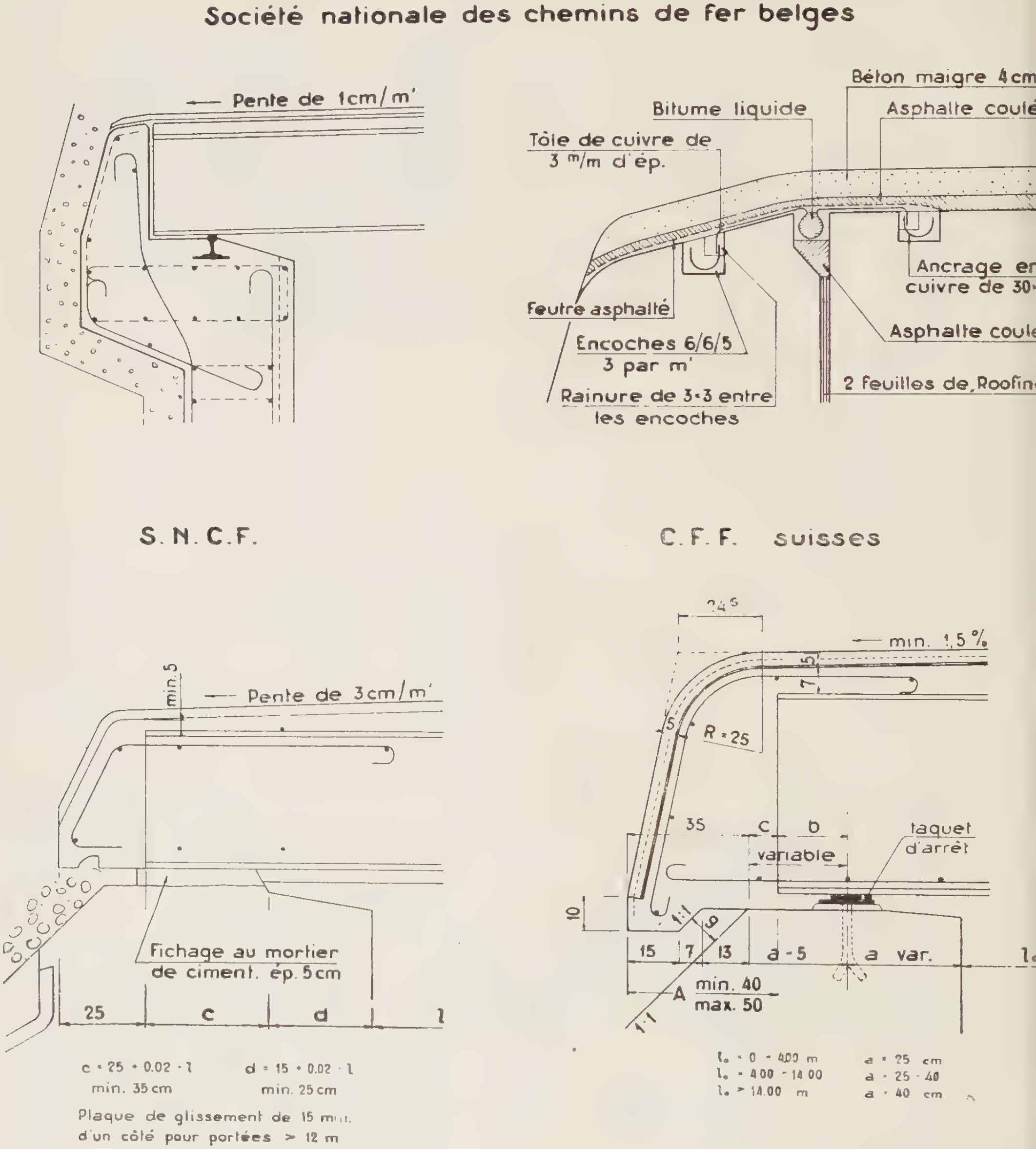
Chape d'étanchéité = Watertight covering. — Répartition = Distribution. — Prolongement de la courbe d'extrados = Prolongation of the curve of the extrados. — Béton ou maçonnerie = Concrete or masonry. — Joint de reprise = Joint for renewal. — Elément tronconique = Pipe section in form of a truncated cone. — Béton ou maçonnerie = Concrete or masonry. — Environ = approx. — Tuyau et coude en fonte ou en fibro-ciment. = Pipe and elbow in cast iron or fibro-cement. — Couvre-joint pour ponts exécutés en deux étapes = Cover plate for bridges erected in two stages. — Couvre-joint de voûte pour retombée = Cover plate for springing of arch of vault. — Béton armé = Reinforced concrete. — Couvre-joint horizontal dans la partie centrale. = Horizontal cover plate for the central portion. — Revers d'eau en béton armé Type S. N. C. F. = Reinforced concrete overfall S. N. C. F. type. — C. F. F. Suisses = Swiss Federal Railways — Chape de protection 4 cm = Protective covering 4 cm. — Isolation, 2 couches = Insulation, 2 layers. — Treillis = Wire netting. —1/2 tuyau en ciment = 1/2 cement pipe. — Tôles en cuivre = Copper plates. — Remplissage = Filling.



Explanation of French terms :

Béton maigre 4 cm = Poor concrete 4 cm. — Asphalte coulé 2 cm = Poured asphalt 2 cm. — Quadrillage = Chequer plates. — Danemark = Denmark. — jute bitumeuse 5 mm = 5 mm of jute impregnated with bitumen. — Chape ciment = Cement covering. — La disposition de l'accotement peut varier = The side spacing arrangment may be varied. — Tous les 60 cm en quiconce = Every 60 cm staggered by fives. — Métal déployé = Expanded metal. — Tous les 30 cm barres ⌀ 12 à 18 suivant portée = Every 30 cm, bars ⌀ 12 to 18 according to the span. — Norvège = Norway. — Chape ciment 3 cm avec treillis — Cement covering 3 cm with wire netting. — 2 couches de carton bitumé = 2 layers of boards impregnated with bitumen. — C. F. F. Suisses = C. F. F. Switzerland. — Pierre de taille ou béton préfabr. = cut stone or prefabricated concrete. — Chape étanche 1 cm = watertight covering 1 cm. — Chape mortier 4 cm = mortar covering 4cm. — Treillis = Wire netting. — Simple voie = Single track. — Double voie = Double track.

PLATE 20. — **Ends of the bridge flooring built up with beams encased in concrete.**

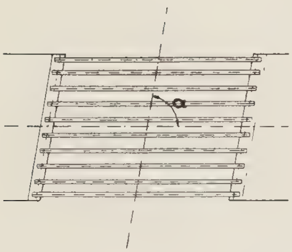


Explanation of the French terms :

Société Nationale des Chemins de fer belges = Belgian National Railways. — Bitume liquide = Liquid bitumen. — Tôle de cuivre de 3 mm d'épaisseur = Sheet copper 3 mm thick. — Feutre asphalté = Asphalted felt. — Encoches 6/6/5 3 par m = Slots 6/6/5 3 per m. — Rainure de 3 × 3 entre les encoches = 3 × 3 groove between slots. — Béton maigre 4 cm = Poor concrete 4 cm. — Asphalte coulé = Poured asphalt. — Ancrage en cuivre de 30 × 3 = Copper anchoring 30 × 3. — Asphalte coulé = Poured asphalt. — 2 feuilles de « Roofing » = 2 sheets roofing felt. —Pente de 3 cm/m = Fall of 3 cm/m. — Fichage au mortier de ciment ép. 5 cm = Fixed with cement mortar 5 cm thick. — Plaque de glissement de 15 mm d'un côté pour portées > 12 m = Slide plate 15 mm thick on one side for spans > 12 m — Taquet d'arrêt = stop.

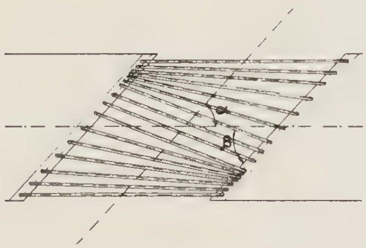
PLATE 21. — **Diagrammatic arrangement of girders on skew bridges according to the S. N. C. F.**

$\alpha > 70°$



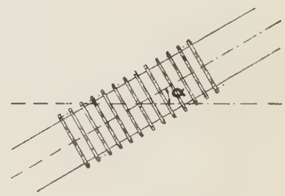
Girders parallel to the track.

$70° > \alpha > 30°$



Central girders following an angle intermediate between the skew angle and 90°. Girders abutting and set fanwise, the end ones being set parallel to the track.

$\alpha < 30°$

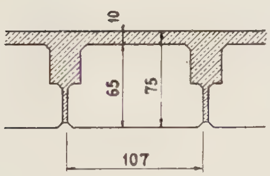


Covered in cuttings with girders at right angles to abutments. Triangular butt joints. dealt with separately.

PLATE 24. — **Railway bridges of presstressed concrete for the Swiss Federal Railways.**

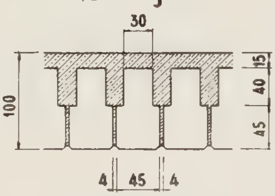
a) Beams entirely prestressed.

Fribourg



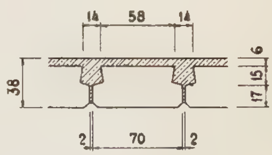
Span 11.00 m
Built in 1943.
Wires ∅ 5.5 mm
Breaking strength 137 kg/mm²
Freyssinet anchoring
Prestressed cross section

Zwingen



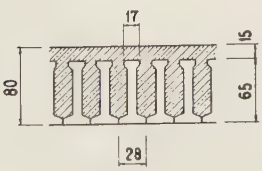
Span 12.00 m
Built in 1947
Wires ∅ 6.0 mm
Breaking strength 162 kg/mm²
Freyssinet anchoring
Prestressed cross section

Saland

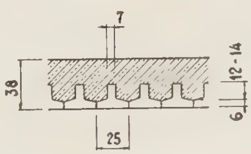


Span 4.40 m
Built in 1944
Twisted wires 4 × 26 mm
Breaking strength 165 kg/mm²
Simple adhesion
No prestressed cross section

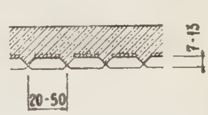
b) Mixed systems with prestressed components.



Span 10.50 m
Hammered wires ∅ 7 mm
Breaking strength 171 kg/mm²
Simple adhesion



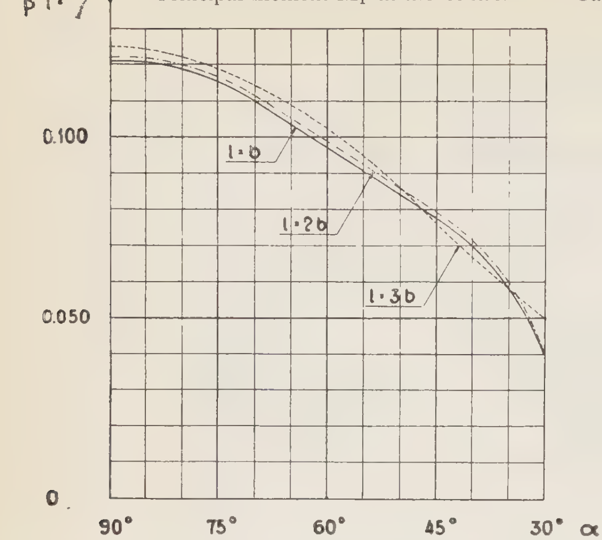
Spans 2.40 m — 4.00 m



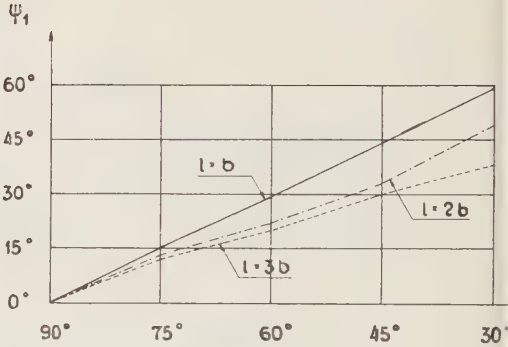
Spans 4.00 m — 9.10 m
Twisted square section wires [·] 4.5 mm
Breaking strength 150 kg/mm²
Simple adhesion

PLATE 22. — **Solid skew plates. — Value and direction of the principal moment as a function of the s**

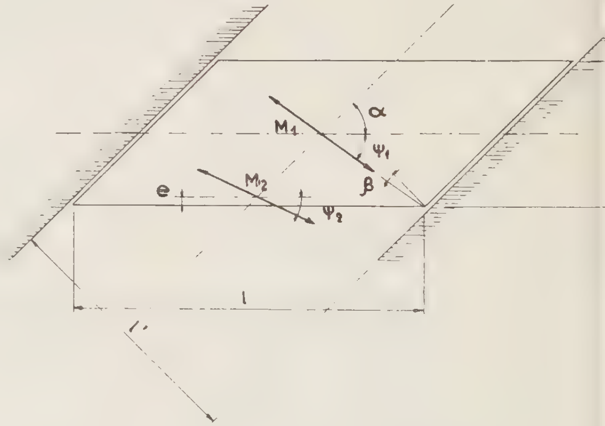
Principal moment M_1 at the centre. Case of the load being distributed uniformly over the whole of the



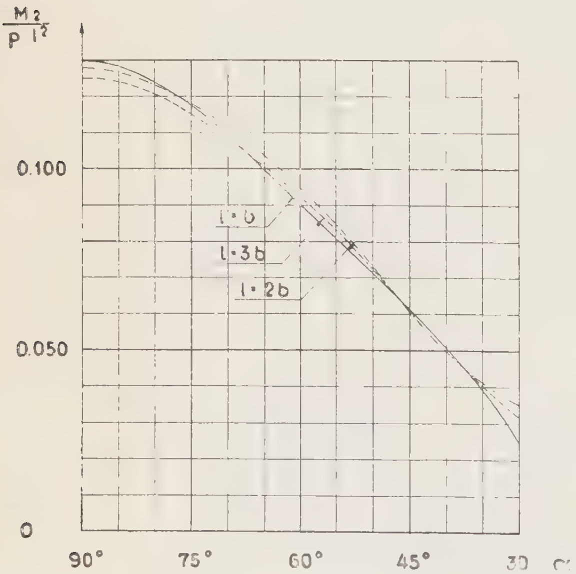
Direction principale Ψ_1 au centre



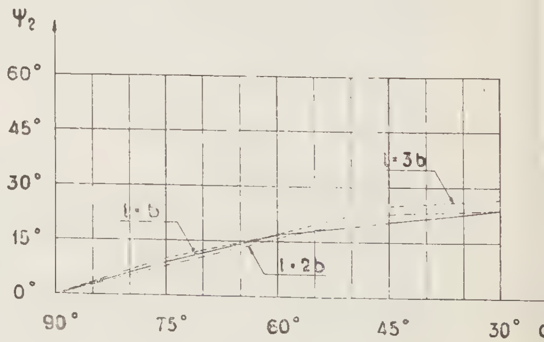
Tests on models constructed by the Statics Laboratory of the Polytechnic of the University of Lausanne for the Swiss Railways (



Moment principal M_2 au bord, à une distance $\underline{e}$ du bord égale à l'épaisseur de la dalle



Direction principale Ψ_2 au bord



Poisson coefficient $v = 0.33$

Explanation of French terms :

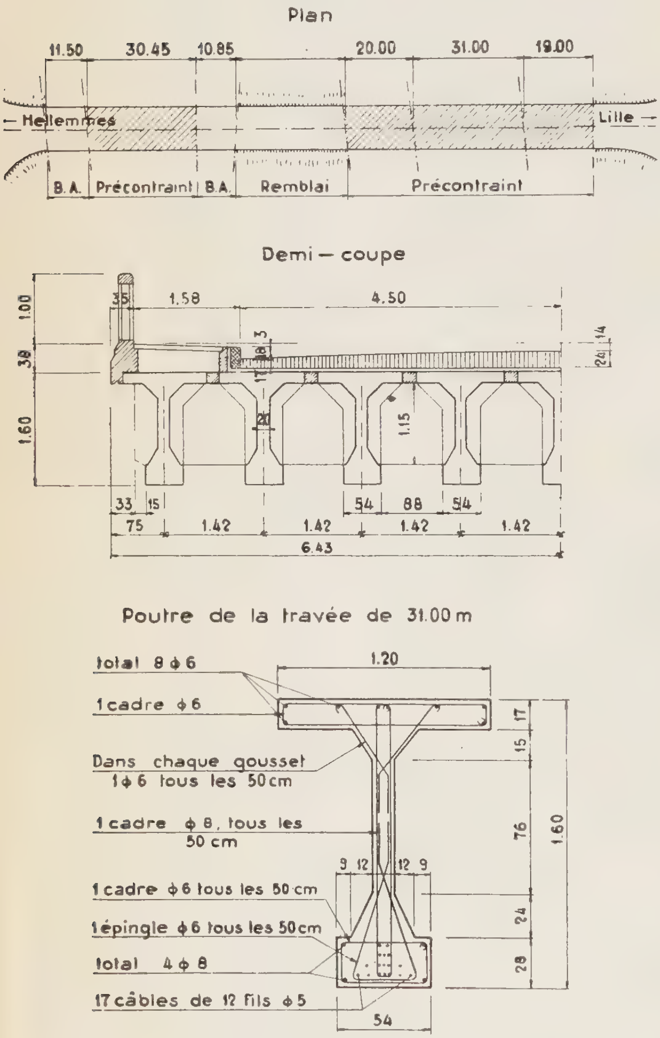
Moment principal M_2 au bord, à une distance *e* du bord égale à l'épaisseur de la dalle = Principal moment M_2 at the edge, at a distance *e* from the e to the thickness of the plate. — Direction principale Ψ_1 au centre = Principal direction Ψ_1 at the centre. — Direction principale Ψ_2 au bord = Principal Ψ_2 at the edge.

PLATE 23. — **Characteristics of concretes for railway bridges made in ferro-concrete.**

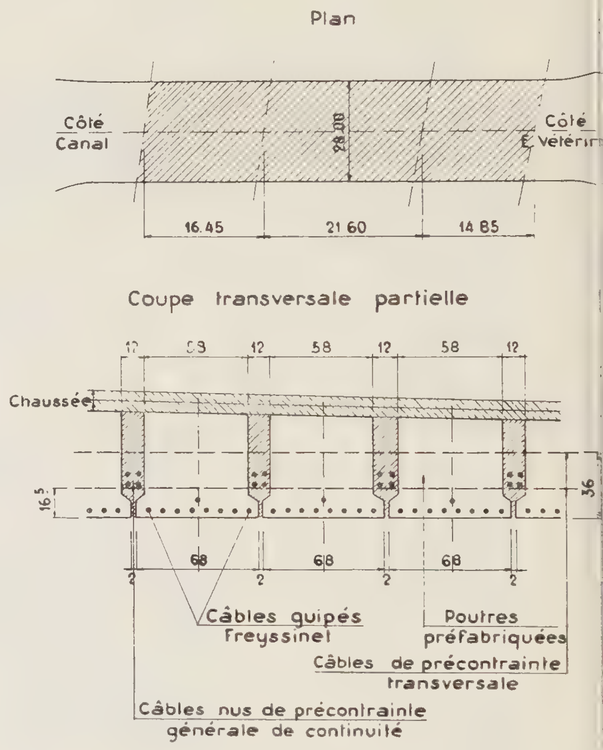
	Belgium S.N.C.B.	*Denmark*	*France* S.N.C.F.	*Netherlands*	*Norway*	*Switzerland* C.F.F.	*Tunisia*
Cement content in kg per m³ of concrete	350	300 to 350	350	350	350; in exceptional cases 400	300	350
Granulation	400 *l*. sand 800 *l* gravel 5/20 or 400 *l* sand and 900 *l* gravel 0/30	Determined to suit prevailing conditions.	Sand 0.2-6.3 mm, gravel 8-31.5 mm. Relative quantities fixed with a view to obtaining a consistent mixture for concrete with a minimum of sand, account being taken of volume of metal parts and their dimensions together with the means available for shaking up.	Sand : 0.15 — 7.5 mm Gravel : 7.5 — 32 mm see diagram fig. 54.	Concrete quality B * exceptionally quality A.	Light works : sand/gravel 0.30 mm added in 2 or 3 separate components, granulation according to curve fig. 54. For big heavy work a special granulometric study is made.	Concrete strong mix according to French practice.
Consistency	As little water as possible	Quantity of water regulated according to ease of handling.	Density $= \frac{\text{vol. absolute mat. secs}}{\text{vol. concrete}}$ = 0.840 to 0.859 (freshly made concrete)	Min. of water to give ease handling.	Ratio water/cement = 0.6 *except. 0.5	Mix. 100-150 water per m³ according to the facilities prevailing.	As dry as possible Slump-test $\sim$ 2 cm
Vibration	Vibration of the whole mixture. At times vibration of the shuttering.	Rarely used.	Internal vibration	Internal vibration	Cylindrical vibrators.	Internal vibration (pervibrators)	Pervibration at times including the shuttering

PLATE 25. — **Presstressed concrete road bridges** (Recent work carried out by the S. N. C. F.)

Mont-de-Terre overbridge.



Matabiau-Toulouse Bridge.



Explanation of the French terms :

lan = Diagram. — Précontraint = Presstressed. — Remblai = Filling. — Demi-coupe = Half-section. — Poutre de la travée de 31.00 m = Reinforced co m of the 31 m span.— 1 cadre ⊂ 6 mm — 1 frame of 6 mm ∅ wire.— Dans chaque gousset 1 ∅ 6 tous les 50 cm = For each gusset 1 ∅ 6 mm wire every 50 cm.— 1 ' mm, tous les 50 cm = 1 frame of ∅ 8 mm wire every 50 cm. — 1 épingle dia. 6 tous les 50 cm = 1 ∅ 6 mm single wire every 50 cm. — 17 cables ∅ 5 mm. = 17 cables of 12 ⊂ 5 mm wires.— Côté canal = Canal side. — Côté vétérinaire = Veterinary College side. — Coupe transversale partielle = Part of th ion of the roadway. — Chaussée = Roadway. — Câbles guipés Freyssinet = Covered cables Freyssinet. — Poutres préfabriquées = Prefabricated bea les de précontrainte transversale — Cables for prestressed cross section. — Câbles nus de précontrainte générale de continuité = Bare cables for g tinuous prestress.

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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION V.

Improvements in the construction of rolling stock (motor and trailer) in view of increasing the mileage between repairs :

- **solid wheels or with tyres (metal used for the tyres and solid wheels, behaviour in service);**
- **axle boxes;**
- **wearing and friction metals;**
- **springs (qualities, shape, manufacture).**

REPORT

(Belgium and Colony, Denmark, France and French Union, Luxemburg, Norway, Netherlands and Colonies, Poland, Switzerland and Syria),

by Georges CHAN,

Ingénieur en Chef au Service du Matériel et de la Traction de la Société Nationale des Chemins de fer français à Paris.

This report has been drafted with the information received in reply to a questionnaire of 47 Questions sent by the General Secretary of the International Railway Congress Association to Member Administrations. Only 48 Administrations were concerned, belonging to the above-mentioned countries, and 30 of them have replied.

We wish to thank here the Administrations, who have answered the questionnaire.

Our report has been drawn up in five parts dealing respectively with steam locomotives, railcars with internal combustion motors, electric rail motor coaches, and coaches and wagons. The summary heading the report is common to the five parts.

SUMMARY

General Questions (Nos. 1 to 3).

During the last few years particular attention has been given to the costs of maintenance of rolling stock. The cost of labour and the intensive use of rolling stock which has to withstand heavier loading and higher speeds have caused the expenditure on maintenance to increase. It appeared, therefore, desirable to investigate those constructional arrangements of the stock which would reduce the costs of repairs.

Then, too, modern machines cost a considerable amount of capital and each day the stock is immobilised means a substantial loss corresponding to the fixed financial charges on the machine.

In these reasons lies the importance of Question V before the Congress, this question dealing with the improvements made

in the details upon which depend to a large degree the mileage between repairs. These details are the running gear, i.e., the wheels, the axle boxes and the metal parts subject to wear and rubbing of the frame and springs.

The replies received immediately confirmed the opinion that the mileage of rolling stock was in general determined by wear or by defects developing in the details mentioned above. The only difference is that the importance attached to a particular detail varies. If in general the wear of the tyres is the controlling factor, the Netherlands Railways point out that in the case of their steam locomotives the maximum allowable wear in the axle box bearings is reached as quickly as the limit of tyre wear.

The replies are unanimous on the value of the perfected modern locomotives.

Although the locomotives designed specially to reduce the times out of service have been put into use only recently, some Administrations have already reported tangible results.

The French Railways (S. N. C. F.) which built in 1943 some mixed traffic engines type 2-8-2 P, with strengthened frames and ordered from the U. S. A. in 1945 a number of mixed traffic engines type 2-8-2 R, with one piece cast steel frame, some with roller bearing axle boxes on the driving axles, report that the average mileage between lifting has risen from 70 000 km (44 000 miles) to 100 000 km (62 000 miles) with the 2-8-2 P, and to 120 000 km (75 000 miles) with the 2-8-2 Rs with monobloc frames and even to 140 000 km (87 000 miles) for the 2-8-2 Rs with both monobloc frames and roller bearing driving axle boxes. The Netherlands Railways report similar results with their 4-6-0 class 4 000 steam locomotives, the mileage of which has risen from 100 000 km to 160 000 km (100 000 miles). The Swiss Federal Railways state that their carriages built between 1937 and 1949 with one piece wheels, roller bearings and the new type of bogie run three to four times more miles between annual repairs than the old rolling stock. Similar figures are reported for the Swiss electric locomotives both of the C. F. F. lines and of the Bern-Loetschberg-Simplon.

When asked if the building of new stock could be justified to save repair costs the Railway replied that whilst actually the new rolling stock was ordered for other reasons, such as to replace stock destroyed in the War, or to replace engines of inadequate power or obsolete design, advantage was taken of the new building to introduce such improvements as would reduce repair costs. It might be thought that these improvements could be introduced on the existing stock. Actually, few alterations are reported due it would seem to many Administrations having received a substantial addition of new locomotives built or delivered immediately after the War, starting in 1945. The Dutch Railways and the Swiss Federal Railways (on their 58 class RIC vehicles) report the application of roller bearing axle boxes to vehicles in service.

***

A summary of the replies received is given below by bringing together the data relative to the various motors, steam, electric, diesel, carriages and wagons, in order to bring out common tendencies or to mark, should they occur, the differences existing between the various classes of stock.

One piece (monobloc) wheels.
(Questions 4 to 14).

The one piece wheels are used to avoid the displacement or turning of the tyres on tyred wheels especially those braked. They are also used to reduce weight especially on railcars, light units with high acceleration. Some Railways (S. N. C. F. notably) find a reduction in defects such as shelling and flaking the appearance of which is delayed in the metal which is less stretched than that of a tyre.

The use of these wheels which is still

limited (steam locomotives carrying wheels in France and Holland, railcars in France and Holland, electric motor coaches and trailer vehicles in Switzerland). In the present state of production, this type of wheel is found by most Administrations to be more expensive than the tyred wheel in spite of the successive turnings the thickness of rim adopted allows. The C. F. F. (Switzerland) has given a most favourable opinion, however, on their use on their electric motor coaches and trailers.

The results appear to depend upon the quality of the metal and the balance sheet would be altered by heat treating the surface and by any other method of hardening the tread.

The S. N. C. F. point out that the one piece wheel can be made much harder than a tyre which is in tension through being shrunk on. Particulars will be found in the report of the method of surface hardening used as standard practice by the C. F. F. (for carriages and motor coaches) and under trial by the S. N. C. F. (for steam locomotives carrying wheels and tender wheels). It is interesting to contrast this heat treatment of the wheels with that already in use in France for the running surface of rails and the heat treatment of certain tyres already included in the U.S.A. Specification.

Whilst as a general rule the adoption of monobloc wheels is still reserved, it should be noted the C. F. F. has decided to use these one piece wheels on its new light weight vehicles and the S. N. C. F. has adopted them for its electric rail motor coaches and Diesel railcars to be built. As a rule, ordinary carbon steel is used but the S. N. C. F. will use chrome-molybdenum steel on its railcars.

Tyres (Questions 15 to 21).

Increasing the hardness raises appreciably the mileage between returning the tyres as is reported by the S. N. C. F. from the results given by its 2-8-2 R locomotives built in the U. S. A. with harder tyres (90 kg [57.14 t. per sq. inch.] instead of 80 kg/mm² [50.79 t. per sq. inch.]) steel.

From the replies received the tyres can be classed in two groups, 75-85 kg/mm² (47.82-53.97 t. per sq. inch.) (Denmark, France, Switzerland) and 80-90 kg/mm² (Belgium, Holland, Norway) : although slight, the difference between these groups can give appreciable results in service. Few results are reported on the tests of tyres definitely harder such as 100 or 110 kg/mm² (63.49 or 69.84 t. per sq. inch.). The tests on metal treated to give 110 kg/mm² by the C. F. F. on some electric locomotives were unsatisfactory as cracks developed during prolonged braking. A trial of Ni-Cr-Mo steel heat treated to give 120 kg/mm² (76.19 t. per sq. inch.) on the S. N. C. F. on some electric locomotives appears to be very satisfactory but the cost is high. We should note in the data supplied some detailed precautions which may be important such as the facts of not annealing the tyres after manufacture, a method which leaves in the tyre a kind of tempering hardness (all Administrations other than the S. N. C. F. do so) or of using on any one axle tyres of very closely the same hardness (a difference of 15 Brinell is specified by the Netherland Railways against 40 by the S. N. C. F.) and finally the endeavour to get extremely fine machining finish in turning the centres and boring the tyres, which is shown as being a common tendency.

Welding (Question 18). — A repair method in general use is used sometimes to repair flanges (C. F. F. electric locomotives) but rarely to make good the tread. The only examples of this latter use noted are on the Moroccan, the Sfax-Gafsa and Luxemburg Railways and then on thick tyres (55 mm = 2 11/64″) and for flats not exceeding 150 mm (5 29/32″) in length.

The *lubrication of rails* by the locomotives (Question 19) is customary practice on sharp curves : the methods used vary : by oil (S. N. C. F.) colloidal graphite (S. N. C. B.) water or exhaust steam (Netherlands and Luxemburg). The S. N. C. F.

estimate that on curves of less than 500 m (1 640′ 5″) radius the lubrication of the rails doubles their life and increases that of the tyre by 60 %. The general tendency is to lubricate the rails but the wide use of *flange lubricators* on the C. F. F. (Swiss) electric locomotives ought to be noted as this Railway is of the opinion that lubricating the flange alone reduces the wear to a third. This Administration also insists upon the primordial value of connecting together transversely the two bogies of a given vehicle.

Independent wheels (Question 22).

A new layout in which the two wheels of a given axle are made independent i.e. not fixed to the same axle may perhaps change the wear of the tyres. Only one trial of this arrangement has been reported; the C. F. F., which carried it out on a coach, report that the wear was irregular and the test was not followed up. The use of independent wheels on the bogie of the Bugatti railcars of the S. N. C. F. has also been reported but this refers to 8 wheeled bogies of which one axle alone has independent wheels, and is a very special case.

Roller bearing axleboxes.
(Questions 23 to 29).

Roller bearing axleboxes, which represent a progressive development in the Automobile industry, have spread during the last 20 years or more to passenger carriages. They have been fitted to other rolling stock more recently. The replies received show that roller bearing axleboxes are now used on a fairly large number of carrying and driving axles of steam locomotives (Belgium, France, Holland) and on the driving axles of electric locomotives (they are now being tried in Belgium and France on a certain number of units and have been in use for a number of years on the C. F. F. electric locomotives). Their use is provided for on the electric and Diesel electric railcars (France, Holland, Switzerland). As regards carriages and wagons, there is great experience on carriages (France, Holland and Switzerland) which is now being extended to wagons (the Netherland Railways have fitted them to all new wagons since 1945).

The advantages of roller bearing axle boxes reported are the absence of overheating, and the reduction in repair costs.

In the case of steam locomotives the report gives valuable information on the results obtained by the S. N. C. F. from one large class of 282 R locomotives, 700 of which have coupled axleboxes of the usual type and 623 with roller bearing axleboxes or at least on the driving axle. This Administration considers that applying them to the driving axle alone is very effective. The Dutch Railways whilst recording the increase in mileage of their 460 type 4 000 locomotives formulate no definite conclusion. In the cases of their coaches the Administrations agree that hot axleboxes are very rare. The C. F. F. report less than ten on their 300 bogie carriages put into service since 1937 and not one on their railcars since 1935.

Certain defects in roller bearing axleboxes, it should be noted, are reported by certain Railways. Corrosion attributed to steam or water getting into them (the case of some steam locomotives of the Netherlands Railways) : fractures of axle journals in line with the sleeve locating the race on certain types of boxes reported by the S. N. C. F. on its electric locomotives (carrying axles) railcars and coaches and by the Netherlands Railways on its rail motors (this defect is not reported by the Algerian, Belgian, Danish, Norwegian or Swiss Railways). It would appear that all that is needed to overcome such cracks peculiar to certain axles is to increase the diameter above that originally provided. The Netherlands Railways report that the cracks found in their electric motor coaches due to too sharp edges of the dismountable tapered sleeves were not found subsequently after these edges had been rounded off.

The question as to which is the better method of securing roller bearings either by fitted cylindrical sleeve or by conical sleeve does not yet appear to have been definitely settled : the tendency is to consider the latter as the most easily assembled.

As regards devices to prevent the electric current from passing through the rollers in the case of electrified lines (Question 29) the S. N. C. B. and the S. N. C. F. report that they do not use them, whereas the C. F. F. use them generally.

Plain bearing axleboxes other than the ordinary box with lubricating pads or packing. (Questions 30 to 32).

The axle boxes with the oil continuously circulated of the Athermos type are mostly used on tenders, electric locomotives and carriages and of the Friedmann-Stemi type on tenders (S. N. C. F.).

We report the wide use in France on the driving axles of steam locomotives of a type of box consisting of two bearings which completely surround the axle with the joint arranged vertically; lubricating pads are not fitted. The results obtained by the S. N. C. F. are worth reporting in view of the hard service the engines fitted are on.

Present tendencies in the selection of the type of axle box. (Question 36.)

The replies received reveal various tendencies depending upon the rolling stock and services considered.

As regards steam locomotives, the S.N.C.F. would use roller bearing axle boxes if it had to build new locomotives but points out for the locomotives in service the economical solution provided by the ordinary box with double bearings just described. The S. N. C. B. restrict their value to express stock. The Danish, Luxemburg and Norwegian Railways state that they are continuing to use plain bearings.

As regards electric locomotives, the Athermos type boxes are used widely on the S. N. C. F. locomotives but roller bearing boxes are to be used on the new stock for the S. N. C. B., Norwegian and Swiss Railways.

Most railcars have roller bearing axle boxes as do the long distance electric rail motor coaches. The motor coaches on urban Railways are fitted with mechanically lubricated axle boxes of the Athermos type, these being preferred owing to their lower cost and because the inconvenience caused by over-heating is less, the journey length being shorter and the termini near (R. A. T. P. or Paris Metropolitan), North of France Light Railways.

As regards carriages and wagons, the replies received cannot be summarised completely. Some Administrations retain ordinary plain bearing axle boxes or even waste packed (S. N. C. B.), others use roller bearing axleboxes on stock for international services and for interior services plain bearing axleboxes with improved lubrication or Athermos boxes or roller bearing axleboxes (S. N. C. F.), and finally some have adopted the roller bearing axlebox for all new stock to be built (Denmark, Norway) and even for wagons (Netherlands, Swiss Federal Railways).

Wearing and friction metals.
(Questions 37 to 41.)

The replies agree in considering that apart from the tyres the parts the wear of which limits the mileage are the pin joints of the motion (steam locomotives) the guides or slides of the axleboxes (rolling stock in general). The report gives particulars of the materials used on rubbing faces. We note for axlebox guides the increased use of 13 % manganese steel rubbing on the same material, an arrangement tending to take the place of bronze linings working on steel, the general method. Amongst new materials now at the disposal of rolling stock builders are the plastic materials of « céloran » used by the R.A.T.P. (Paris Metropolitan) on its electric rail motor coaches on the Sceaux line and *Mintex*, a fabric with an asbestos base, on the Norwegian fast rail motor coaches.

A method of taking up the play between the axleboxes and guides is the use of the automatic and *self-adjusting wedges* used on the S. N. C. F. steam locomotives (Franklin type wedge which this Railway system reports as being very satisfactory).

Another method of overcoming wear is to replace the rubbing surfaces by controlling the movement of the axlebox by rods fitted with silent block bushes, by rubber blocks or by elastic connections such as plate springs. In addition to obviating wear, these arrangements are reported as eliminating play and ensuring greater comfort as hunting remains restricted. Such arrangements are found on the electric locomotives and recent railcars of the S. N. C. F. and on the Norwegian railcars. The most notable results are those reported by the C. F. F. (Switzerland) which has had several years' experience and which reports most satisfactory results obtained by guiding the boxes by vertical plungers largely dimensioned and case hardened sliding in oil baths (figs. 28 and 38).

Springs. (Questions 42 to 47.)

The type of metal used for laminated springs does not appear to cause any particular worry. The S. N. C. F. calls attention to the value of getting uniform characteristics so as to be able to lay down the same heat treatment for all springs during repairs. It is to be noted in this connection that most of the Administrations lay down the chemical composition (Belgium, Holland, Denmark, Norway) whereas the other Administrations are satisfied to specify the mechanical tests (France, Switzerland).

As regards the manufacture of laminated springs, springs with the *buckles put on cold* are being tested on the S. N. C. F. steam locomotives, a method also being used successfully on the C. F. F. (Switzerland) electric locomotives. *Coiled springs* tend to be used generally on modern bogies (in association with snubbers); some Administrations have given up the use on carriage bogies of round section springs in favour of springs of square or rectangular sections with which fewer cases of cracks are found (Norwegian Railways and C. F. F.). The use of india rubber is widely applied especially in buffing and drawgear (S. N. C. B., S. N. C. F., Algeria, Morocco and C. F. F.) and is stated to be very satisfactory by the S. N. C. F. and C. F. F.

Its use for the suspension gear is not so widely extended. Its application is reported to the spring hanger bolts on steam locomotives (Netherlands Railways) on tenders, and on electric locomotives (S. N. C. F.) and on light weight carriages (C. F. F.).

***

FIRST PART.

Steam locomotives.

A. GENERALITIES.

Question 1. — *State the regulations which govern maintenance and periodic repair of locomotives, carriages, wagons, railcars, etc., What are the conditions of wear of details (e. g. the hollowness of tyre before removal) which have led to the fixing of these regulations?*

Periodical repairs to steam locomotives are the same from one Administration to another.

We find :

a) a repair known as « *heavy overhaul at a depot* », on the S.N. C. B.; « *lifting* », on the S. N. C. F.; « *heavy repair* » on the Netherlands Railways and at which the mechanism is put in good order and the tyres returned. This repair is carried out at regular intervals varying according to the type of locomotive and also according to the Administrations (see table 1).

The intervals between two such repairs are governed by the mileage run, i.e. :

60 000 to 120 000 km (37 000 to 74 000 miles) for passenger locomotives;

48 000 to 100 000 km (30 000 to 62 000 miles) for goods locomotives.

TABLE 1.

Period between steam locomotive repairs.

Below are given as examples the regulations followed by some Administrations :

Mileage and nature of repairs		
S. N. C. B.	Running shed repairs.	10 000 km for passenger locomotives; 8 000 km for freight locomotives — wear of bushes, brasses of couplings and connecting rods.
	Intermediate repairs in running shed.	30 000 km for passenger locomotives; 24 000 km for freight locomotives. — wear of piston rings, injectors and coupling between engine and tender.
	Heavy shed repairs.	60 000 km for passenger locomotives; 48 000 km for freight locomotives. — wear of tyres, piston rings and brasses, brake and spring gear.
	Intermediate shop repair.	100 000 km for passenger locomotivess; 80 000 km for freight locomotives. — more complete than at the previous (guides, cylinders, crank pins, etc.).
	General repairs.	300 000 km for passenger locomotives; 240 000 km for freight locomotives; — complete general repair including boiler and frame.
S. N. C. F.	Intermediate repairs.	Half the mileage between lifts. — to put certain parts into good order without removing the wheels for returning.
	Lifting.	Between 50 000 km and 120 000 km according to the service of the engine. In the case of the 282R locomotives with roller bearing axleboxes throughout, the mileage is fixed at 140 000 km. — wear of tyres, metalling of boxes and rods, rings, taking up wear in the motion, brake gear, springs, fittings.
	General repairs.	Usually on the average at the end of four mileages for lifting and at the end of five in certain cases. — complete repair including boiler and frame.
Morocco.	Valve and piston. examination.	40 000 km inspection of pistons and valves.
	Examination of wheels, pistons, and valves	120 000 km lifting the machine turning tyres and complete overhaul of motor.
	General repairs.	360 000 km complete repairs including the boiler.
Netherlands.	One description only « Heavy repairs »	100 000 km for passenger locomotives; 80 000 km for freight locomotives. The 4 000 class of passenger locomotives now run 160 000 km, when fitted with roller bearing boxes, the 4 300, 4 700, and 5 000 classes good engines 120 000 km. Every seventh year the heavy repairs include the complete overhaul of the boiler.

These mileages have been fixed so that the play or wear of the details and especially of the tyres does not exceed a certain value (S. N. C. F. Morocco, Gafsa allow 5 mm [13/64″] hollow on the tread, the others have not mentioned it). The Netherlands Railways point out that the locomotives usually reach the maximum allowable wear in the boxes before the tyres are worn down to their limit. The Norwegian Railways, whilst agreeing that the tyre wear is the determining factor, point out that the wear of the motion often is frequently equally involved.

b) A repair known as « *general repairs* » at which the engine and boiler are thoroughly repaired and which is usually rendered necessary by the state of the boiler.

c) Between the repairs described operations of minor importance are undertaken and at these wear of rod bearings is taken up, and rings replaced (the Table indicates the nature of these operations, classified as « *minor repairs* » on the S. N. C. B. and « *intermediate repairs* » on the S. N. C. F.). The question which is the object of the present exposé does not touch the regulations relating to boiler repairs. In the present question we are limited to the repercussions on the mileage of the engines of the behaviour of the running details.

Question 2. — *Can it be said generally that mileage between repairs has been increased with improved modern rolling stock and locomotives? If possible give examples.*

Most of the Administrations consulted have been unable to give precise conclusions on the improved mileage obtained with the perfected modern locomotives. Some tangible results however have been reported by certain Administrations.

The S. N. C. F. report that the mileage between lifting which was 70 000 to 90 000 km (43 000 to 56 000 miles) has risen to 100 000 km for its 282-P. mixed traffic locomotive of 1943 with strengthened frame.

120 000 km for its mixed traffic locomotive of 1946 with its reinforced one piece frame.

140 000 km for its mixed traffic 2-8-2 R locomotive of 1946 with in addition complete roller bearing axleboxes on the driving axles, and it thinks that the increases in mileage run are due to the improvements as a whole such as rigid frames, self-adjusting wedges, roller bearings, and harder tyres.

Although the increase in the mileage obtained has not been given, the Gafsa and the Norwegian Railways have confirmed the good results of increasing the hardness of the tyres.

The Netherlands Railways report that with the type 2-8-0 locomotives of the 3400 Class and the type 2-10-0 of the 5000 Class, the mileage has increased from 80 000 to 120 000 km, this improvement being attributed to the large dimensioning of the bearings which will be dealt with later. In the case of the 460 type Class 4000 and 080 type Class 4700 locomotive, the mileage has increased from 100 000 to 160 000 km for the former and from 80 000 to 120 000 km for the latter, by using roller bearing axleboxes on all axles and by fitting adjustable axlebox guides.

Question 3. — *When ordering new rolling stock and locomotives, is consideration given to maintenance costs in the specification, and if when ordering modern stock are endeavours made to reduce these costs? Indicate if the Railway administration endeavours to obtain similar results by the modification of stock in service.*

The locomotive stock has been renewed by ordering new engines and by taking out of service locomotives of 40 to 50 years of age.

The Administrations agree that it is not as a rule only the need to reduce repair costs that inspires the orders for new rolling stock. The engines are acquired either

because of new needs (greater power or adhesion) or as has frequently occurred in recent years to replace stock damaged by war (S. N. C. F., S. N. C. B., Netherlands).

The Administrations agree that in all cases the conception that all new rolling stock to be ordered should take into account the terms used by the Luxemburg Railways of the « primordial value of reducing the high cost of repairs of the old rolling stock ».

The S. N. C. F. point out that in this event the improvements sought for are in connection with the following main points :

rigidity of frame;

roller bearing boxes on all axles or at least special boxes or bearings;

harder steel tyres;

more rigid wheels;

wear resisting metal on axlebox guides and automatic wedges;

double segment (cast iron and bronze) piston rings;

pins and bushes machined to standard limits.

Reduction in repair costs are also sought by alterations to rolling stock in service which in the absence of new stock can also produce economies. These alterations are only made to locomotives expected to be retained in service for some time longer. The alterations reported as having been done are not very important and do not form a great transformation of the engines.

B. SOLID WHEELS.

Question 4. — *Have you had experience with solid wheels?*

Forged steel solid wheels are used on steam locomotives in *France and Holland.*

On the S. N. C. F., 1323 locomotives of the 282-R type built in the *U. S. A.* in 1945-1947 have such wheels on the leading truck (914 mm [2′ 11 21/32″] diameter) and on the trailing truck (1 067 mm [3′ 6 23/64″] diameter). These wheels are forged steel and the tyre thickness is 63.5 mm (2.5 in.) on the leading truck and 76 mm (2.99 in.) on the trailing and on the tender. [1]

On the Netherlands Railways the tenders of the 2-8-0 and 2-10-0 locomotives acquired in 1945-46 from the War Office have one piece wheels 965 mm (3′ 1 61/64″) in diameter.

Question 5. — *If so, what are the results which you have obtained or hope to obtain by using solid wheels from the point of view of regularity of the service? What are the advantages and disadvantages already established?*

The one piece wheels on the S. N. C. F. 2-8-2 R locomotives give satisfactory results from the technical aspect.

The Netherlands Railways have found no drawbacks and report some flaking or scaling attributable to defective pouring of the metal and which are neither more nor less frequent than with tyred wheels.

Although there is still insufficient experience to state precisely the *advantages of a technical character* obtained by using one piece wheels, the S. N. C. F. consider the following advantages may be agreed :

removal of the risks of tyres turning or coming off;

possibility of wearing the tyres further;

ability to use a quality of steel harder than when the tyre is shrunk on, with less risk of fracture;

less flaking or folding of the metal due to the rolling surface not being under shrinkage stress.

The S. N. C. F. state it has found that flaking is less frequent than on tyred wheels.

Question 6. — *The same question from the cost point of view.*

The S. N. C. F. has had to order replacement one piece wheels in sufficiently

[1] The thickness in question is defined as half the difference between the diameter of the rolling circle and the inside diameter of the tyre measured on the outer face.

important numbers to be able to form an opinion on the economical aspect of the question. Under the present manufacturing conditions and for the mileages obtained, the use of one piece wheels appears to be more costly. This aspect of the question would seem to be capable of improvement in future if the mileage can be increased by a surface hardening treatment of the tread. It is possible that the extended use of such wheels will lead to improved manufacturing methods and lower costs. The S. N. C. F. is of the opinion that the experience with one piece wheels should be continued both from the economical and the technical points of view.

Question 7. — *Do you use solid wheels on vehicles running at high speeds?*

The one piece wheels are used on mixed traffic locomotives running at 90 km/h. (56 m. p. h.) (S. N. C. F.) or on tenders running at 65 km/h. (40 m.p.h.) (Netherlands Railways).

Question 8. — *Do you use them on braked vehicles (braking on running surface, on brake drum, or on the wheel centres)? What material is used for brake shoes? What advantages and disadvantages have been established?*

The one piece wheels are braked in the case of the class 34 R tenders of the S. N. C. F. and the Netherlands tenders and are not in the case of the carrying wheels of the S. N. C. F. 282-R locomotives. When these wheels are braked cast iron brake blocks are used.

No drawbacks have been found.

As to the advantages, the adoption of the one piece wheel does suppress any movement of the tyre under prolonged braking.

Question 9. — *What metal is used for solid wheels (chemical analysis and physical characteristics)?*

Question 10. — *Do you use special methods of manufacture in order to obtain the appropriate characteristics of the metal in the different parts of the wheel?*

Table 2 gives the characteristics of the metal of the one piece wheels used by the S. N. C. F. with details of the nature of the steel of the original wheels of U. S. A. manufacture and of the replacement wheels made in France.

In view of the importance of increasing the mileage before turning up the treads the S. N. C. F. is experimenting with *surface hardening* of the rolling surface of wheels made of HH steel mentioned below with the object of getting the peripheral zone of the wheel much harder whilst the rest of the wheel remains unchanged. The process consists in raising the wheel to the proper temperature, then by suitable equipment to revolve the wheel with its axis arranged horizontally with a certain thickness of the tyre dipping in a stream of water. After cooling, the wheel is heated in a tempering furnace.

This kind of treatment may be contrasted with that by surface hardening already used in the U. S. A. for tyres.

From the information supplied by the S. N. C. F. the above surface treatment does not reduce the resilience of the zone treated and under shock test, like a tyre, the peripheral zone if cut away from the wheel disc gives results showing no particular fragility. After treatment the Brinell hardness number is raised from 260 to 300 at 30 mm (1 3/16″) below the running surface, 320 at 5 mm (13/64″) below and 360 in the flange.

The S. N. C. F. is not yet able to give the results obtained in service with wheels with hardened surfaces.

Question 11. — *Can the solid wheels which you use be re-profiled, by the depositing of metal, by turning, etc., and what are the thickness limits in each case?*

TABLE 2.

Characteristics of the metal of the one piece wheels on the 2-8-2-R locomotives of the S. N. C. F.

Type of wheel	Kind of steel	Composition %							Heat treatm.	Mechanical characteristics		
		C %	Mn %	Ni %	Si %	P %	S %	Various (indiv.)		R kg/mm^2	A %	K UF
American wheels (American ASTM-A-57-42 specification)	Martin or Electric steel, rolled	0.67 to 0.82	0.60 to 0.85	—	0.15 min.	0.05 max.	0.05 max.	—	not treated	not specified		
French wheels (HH steel of STU No 301 A).	Martin or Electric forged or rolled	—	1.00 max.	0.50 max.	0.50 max.	0.05 max.	—	0.25 max.	not treated	80 min.	12 min.	2 min.

Question 12. — *In the case of wheels having flats do you repair on site by building up by welding and making good the tyre surface by grinding or turning?*

The S. N. C. F. reports that the one piece wheels of its 282-R locomotives are at the moment restored to the correct profile by turning in a wheel lathe. The second Administration using one piece wheels, the Netherlands Railways, also had not carried out repairs by adding metal by welding.

The one piece wheels of the S. N. C. F. 282-R locomotives are returned when worn down to the limits of 38.5 mm (1.50 in.) for the 63.5 (2.50 in.) and 76 mm (2.99 in.) initial tyre thickness and 40 mm (1.54 in.) for 90 mm (3.54 in.) initial thickness tyres introduced in France during repairs.

Question 13. — *After several returnings are you able to retyre wheels which originally were solid wheels?*

Tyres 63.5 mm and 76 mm thick, such as those used by the S.N.C.F. on its American built 282-R locomotives cannot be tyred when worn to their limit. This Administration states it can re-tyre the 90 mm thick wheels after being turned up a number of times with new 75 mm tyres but is not doing so at present as it wishes to make a prolonged test of the one piece wheels.

The Netherlands Railways have not decided whether to re-tyre or not the one piece tender wheels.

Question 14. — *List the defects such as shelling, scaling, radial cracks or others? Are these defects more or less frequent with solid than with tyred wheels?*

Defects, such as shelling, having been found with the one piece wheel but not more frequently than on tyred wheels (Netherlands Railways) and less frequently (S. N. C. F.). More experience is needed before a definite comparison can be made.

***

Steam locomotive

ADMINISTRATION	Kind of steel	Compo				
		C	Mn	Ni	Cr	Mo
BELGIUM-LUXEMBURG. *S. N. C. B.* *Luxemburg Railway* *Matadi-Léopoldville Railway* *Bas-Congo to Katanga Railway*	Class Y carbon steel to specification A-13-45 of the S. N. C. B. either Martin, Electric or crucible. Special Z. R. steel	—	—	—	—	—
DENMARK. *State Railways*	Siemens Martin or crucible carbon steel.	—	—	—	—	—
FRANCE. (*a*) Standard tyres. *S. N. C. F. and Algerian Railways* *Gafsa Railway* *Morrocan Railways* *Damas-Hama Railway*	A 75 d carbon steel. STU No. 14 K, Martin or electric.	—	1.20 max.	0.50 max.	—	—
S. N. C. F. (*b*) American tyres of the 282 R	Class B carbon steel of American specification AAR-EM 106-42. Martin or electric furnace.	0.60to0.75	0.50to0.75	0.25 max.	0.15 max.	—
S. N. C. F. (*c*) Trial of tyres in hardened steel for wheels of carrying axles of 2 loc. 282 P	Bedel crucible steel BNAV 2.	0.25	—	3.80to3.96	0.98to1.10	0.50
HOLLAND. *Netherlands Railways*	Carbon steel Type St 80-92. Type Qmc 70-80.	0.60 0.60	— —	— —	— —	— —
NORWAY. *State Railways*	Special steel.					No deta
SWITZERLAND. *C. F. F.*	Carbon steel.					N

teels.

%					Heat treatment	Mechanical characteristics
	P	S	P + S	Various (each)		
	0.05 max.	0.05 max.	0.09 max.	—	Makers option	R = 80 to 90 kg/mm². A % minimum : 11 % measured on length L = 5 diameters. Reduction area : 25 %. Resilience : K = 2 kg/cm² with test bar with 5 mm deep notch.
	0.04 max.	0.04 max.	0.07 max.	—	—	R = 75 to 85 kg/mm². A = 12 % measured on 100 mm of a test bar 20 mm in diameter.
0 x.	0.05 max.	0.05 max.	0.09 max.	0.25 max.	Treated with specified reheat to 825° Not quenched in any liquid.	R : 75 to 86 kg/mm². A % = minimum 12 % on bar UF). Resilience K = 2 kg/cm² (on bar UF Brinell hardness : difference between the two tyres on one pair of wheels must not be over 40 units.
	0.05 max.	0.05 max.	—	—	—	— Drop test. R = 81 kg/mm². A % = minimum 10 %. Reduction of area minimum 14 %.
	—	—	—	—	Oil hardened and tempered at 600°	R = 120 kg/mm². E = 110 kg/mm². A = 12 %. Resilience = 10 kg/cm².
	0.04 max. 0.06 max.	0.04 max. 0.06 max.	0.07 max. 0.10 max.	— —	Makers option	R = 80 to 92, E = 40, A = 10 % R = 70 to 80, E = 35 A = 12 % on each tyre : Brinell = 228-266 the values for the two tyres on an axle not to differ by over 15 units.
					—	R = 80 to 92 kg/mm². A = 9 to 8 % measured on a length = 10 d.
ation						R = 70 to 80 kg/mm². A = 13 % measured on 1 = 10 d.

T

Methods used to

ADMINISTRATION	Methods of fastening the tyre used or under test	Closeness of finish machining of contact sur of tyre and centre finish cut with tool
BELGIUM *S. N. C. B.*	Not given.	*Rim* : radius + 0.5 mm advance tour. Tolerance for ovality ± 0.15 *Tyre* : finish cut with former not vance. Tolerance for ovality ± mm.
DENMARK *State Railways*	Held by holding ring.	—
FRANCE *S. N. C. F.*	*Standard fastening* : retaining ring sprung in a groove in the tyre at an angle to the plane of rolling. *Test fastening* : for hard tyres or with the tread surface hardened. By *ring not forced on* (to avoid knocking over the lip) in a groove at right angus to the rolling surface. *Fastening by shrinkage without retaining ring* following American practice on 700 locomotives of the 282 R type. System given up owing to many slack tyres.	No special precaution but the tend is to equip some lathes specially t better machined surfaces.
Algerian Railways	Standard fastening with ring.	The contact surfaces are finished wi former on the lathe. A test of metal deposit on the rim the tyre by the shop process has g good results but has not been i duced generally.

he tyre to the wheel centres.

Shrinkage used	Method of heating tyre	Possible use of welding. Remarks
New parts : fitting H 9X8, i. e. 1.4 to 1.75 mm per m of diameter of the rim. Replacement parts 0.001 D + 0.5 mm/m (D = mean diameter of the rim in mm).	Coal fired furnace.	The tyre is never welded to the rim.
1.3 to 1.4 mm per m of diameter of the rim.	—	The tyre is not welded to the rim.
1.3 mm per m of diameter of the rim. The allowance is reduced to 1 ‰ for mounted, wheels.	Gas or oil fired furnace.	No test has been made to weld, even by spod welding, the tyre to the rim to prevent it from turning.
1 to 1.3 mm per m. of diameter of the rim.	Induction heating	The tyre is not welded to the rim.

TABLE

Methods used to secure

ADMINISTRATION	Methods of fastening the tyre used or under test	Closeness of finish machining of contact surfaces of tyre and centre-finish cut with tool
Gafsa Railway	Secured by 4 set screws 18 mm diameter though the rim and tyre.	—
Damas-Hama and extensions Railways	Secured by retaining ring.	The contact surface ought not to show more than very light tool marks.
Indo-China Railways	Not specified.	Smooth machined surfaces.
HOLLAND. *Netherlands Railways*	Not specified.	Contact surfaces to be turned as smooth as possible.
LUXEMBURG. *Luxemburg Railways*	Secured by retaining ring.	The contact surfaces are given a very fine finish.
NORWAY. *State Railways*	Not specified.	Considering the acquisition of boring machines and high speed lathes for very hard tools toget the smoothest possible finish of the contact surfaces.
SWITZERLAND. *C. F. F.*	Secured by retaining rim.	The instructions lay down smooth turned, or with former, bearing faces of the tyre and rim.

e to the wheel centres. *(Continuation)*

Shrinkage used	Method of heating tyre	Possible use of welding Remarks
—	Circular furnace with 3 crude oil burners.	The tyre is not welded to the rim.
nm per meter of outside dia. ' the rim.	Heated to 415° in an oil fired furnace.	It is not usual practice to weld the tyre to the rim to prevent it turning.
nm per meter of outside dia. ' the rim.	Heated with wood.	The tyre is not welded to the rim to prevent it turning.
ying wheels : to 1.3 mm per meter of outside a. of the rim. *ing and coupled wheels* : 2 to 1.4 mm per meter.	Circular gas furnace.	The tyre must not be welded to the rim nor shims interposed between them. If oval, the diameter of the rim can be corrected by adding weld metal.
of the bore : $\leqslant$ 1 400 mm .4 $\pm$ 0.1) mm per m of ⌀ bore. of the bore $>$ 1 400 mm .2 $\pm$ 0.1) mm per m.	Gas burners placed round the circumference of the tyres.	The tyre is not welded to the rim.
to 1.65 mm per meter of iameter of rim.	Heated by gas or electric resistance heating.	Welding is not used.
o 1.6 mm per meter of outside iameter of rim. to 1930, shrinkage was only 1 ‰).	Induction heating.	The tyres are not welded. Tests made 15 years ago showed that the point of welding regularly caused cracks to start.

TABLE 5.

Minimum thickness of tyre.

Administration	Types of locomotives, axles, or kind of service worked	Minimum thickness of tyre	
		After repair, after last turning. in mm	limit of wear in service, before withdrawal. in mm
BELGIUM. *S. N. C. B.*	For all axles of all locomotives other than those with heavy axle loading sor running on hilly lines	35	30
	For locomotives with high axle loads or running over hilly lines.	40	35
Matadi to Léopoldville Railway	All stock	—	1/3 of thickness when new
DENMARK. *State Railways*	Axle loaded under 10 t.	—	27
	Axles with loads of 10 to 15 t.	—	32
	Axles loaded at 15 t or more.	—	37
FRANCE. *S. N. C. F.*	Coupled axles of certain series of powerful steam locomotives	50	45
	Coupled axles of other classes of modern steam locomotives.	45	40
	Coupled axles of old steam locomotives and shunting engines	40	35
	Unbraked carrying axles of modern steam locomotives (1)	do	do
	NOTE (1) The limits are increased by 5 mm when these axles are braked.		
Algerian Railways	Locomotive wheels equal to or above 1 300 mm.	42.5	40
	Locomotives wheels under 1 300 mm diameter.	37.5	35
Moroccan Railways	Coupled axles of 460 A, 282 LT, 282 A and 280 USA and tenders 20 USA.	—	40
	Carrying axles of locomotives 282 A.	—	35
	Carrying axles of locomotives 460 A, 282 LT, tenders 17 and 35	—	30
	All axles of locomotives 060 A and tenders 10.	—	30

TABLE 5.

Minimum thickness of tyre *(continued).*

Administration	Types of locomotives, axles, or kind of service worked	Minimum tyre thickness	
		After repair, after last turning. in mm	limit of wear in service, before withdrawal. in mm
Gafsa Railway	All types of engines	48	43
Damas-Hama and extensions Railways	All types of locomotives	40	35
	Tenders.	35	30
Indo-China Railways	All types of locomotives	—	35
	Tenders	—	30
S. G. des Ch. de f. Economiques (meter gauge) (Brittany System)	Locomotives type A	40	35
	Locomotives type B	35	30
HOLLAND. *Netherlands Railways*	Driving and coupled axles : according to the types of locomotives	40 to 55	—
	Braked carrying axles	35	—
	Unbraked carrying axles	30	—
	Tender axles : according to the type of tenders .	30 to 40	—
LUXEMBURG. *Luxemburg Railway*	Powerful goods locomotives coupled axles. .	45	40
	Powerful locomotives carrying axles	40	35
	Coupled and carrying axles of the other locomotives	40	35
	Tender axles	35	30
NORWAY. *State Railway*	Main line locomotives	40	—
	Small locomotives on secondary lines	25	—
SWITZERLAND. *C. F. F.*	All main line locomotives :		
	Driving and coupled axles	40	35
	Carrying axles.	35	30
	Other steam locomotives (all axles) and tenders.	35	30

C. TYRED WHEELS.

Question 15. — *What quality of metal of tyres (chemical analysis and physical characteristics, method of manufacture and especially type of heat treatment)?*

Table 3 gives the information from the various Administrations. To summarise the Table as a whole we can say from the point of view of hardness there are two classes of tyres — 75-85 kg/mm² (S. N. C. F., Denmark) and the harder 80-90 kg/mm² (S.N.C.B., Netherlands Railways, Norway).

Except for special tests, the tyres are not tempered. The S. N. C. F. tyre, however, must be annealed after rolling whereas those for other Administrations are allowed to cool after rolling and are consequently harder. No particular hard steel is indicated as being in general use and investigations into such steels are still in the experimental stage. The Table gives particulars of the S. N. C. F. test of a special Ni. Cr. Mo. steel intended to bring out the value of steel of very high quality. More detailed results are given in connection with the electric locomotives in the 3rd part, to which the reader is referred.

It is interesting to point out that certain Administrations insist on the two tyres of a given axle being of nearly the same hardness. The variations allowed, however, are very different (40 Brinell units on the S. N. C. F. and 15 on the Netherlands Railways).

Question 16. — *What are the measures that you have adopted to reduce to a minimum the risk of loose tyres? (State of surface after machining, diameters of the wheel centres and tyres in contact before mounting, system of heating tyres, etc.). Do you weld at the rim to prevent loose tyres?*

Table 4 shows the method of fastening used, the shrinkage allowed, special methods of heating the tyre for shrinkage and all measures introduced to reduce risks of the tyre coming loose.

This Table shows that the Administrations generally agree as to the importance of machining with great care the surfaces of the tyre and the wheel which will come together.

The lowest shrinkage allowances are 1 to 1.3 mm per metre (0.0393 to 0.0511 in.) (Algerian and Netherlands Railways) and the highest 1.2 to 1.6 mm per metre (0.0472 to 0.0629 in.) (*Belgium, Norway, Sweden*).

No Administration reports welding the tyre to the wheel. The C. F. F. reports that tests made 15 years ago showed that the points of welding regularly started cracks.

Question 17. — *What are your specifications regarding the minimum thickness of tyres according to the load or maximum speed permitted for vehicles (minima both after repair and in service)?*

Table 5 below gives the minimum thickness of the tyre on the tread allowed by the Administrations either after the last turning up or in service before being withdrawn and replaced.

Question 18. — *When wheels have flats do you repair by building up by welding and making good the tyre surface by grinding or turning?*

The Administrations consulted do not allow building up the worn tread by welding and then grinding except however some Railways on which the speeds are relatively low. This is the case on the Sfax to Gafsa Railway when flats on the tyres do not exceed 50 mm (1 31/32″). The metal is added by arc welding using carbon steel electrodes of R = 60 kg/mm², the surface being smoothed down by a portable air driven grinding wheel fastened to the axle. This procedure which has given good results is only used when the tyres exceed 55 mm (2 11/64″) in thickness. The Moroccan Railways repair by building up flats 150 mm (5 29/32″)) long and the Algerian Railways follow the same practice but have given no details. The Luxemburg Railways also use welding but only in exceptional cases.

Question 19. — *In addition to choice of metal and its treatment do you employ other methods to reduce tyre wear (e. g. lubricating flanges or rails)?*

Most of the Administrations having lines with curves of small radius have endeavoured to find means other than the quality of the steel used in the tyres, to reduce the wear of flanges.

The lubrication of flanges tested on the S. N. C.F. and S. N. C. B. has been almost entirely abandoned, the apparatus not being satisfactory or leading to excessive oil consumption. On the other hand the automatic lubrication of the rails is current practice on some Administrations and is under test on most of the others.

The solution with the lubricator on the locomotive seems to have prevailed for the running lines.

As an example we mention the lubricators with a jet of oil pulverised by air used on the S. N. C. F. on lines with frequent curves of 500 m radius or less. From the experience of this Railway System the rails should be lubricated after every 4 or 5 trains or after 500 axles have passed over them. The consumption of oil is 50 g of oil per day per locomotive and per kilometre of track lubricated. The lubrication of the rails doubles the life of the rails and increases the life of the tyres by 60 %.

The S. N. C. B. which is fitting rail lubricators using colloidal graphite on its electrified lines (curves of less than 1 500 m radius) is considering extending their use on curves of 500 m radius on certain lines with many curves run over by steam locomotives.

In addition to the automatic lubrication of the rails on small radius curves the Netherlands Railways have in service steam shunting locomotives of the 0-10-0 type fitted with a device which squirts *water* on the tyre.

The modern locomotives of the Luxemburg Railways are fitted with a special device to lubricate the flanges by exhaust steam.

Question 20. — *Have you found with locomotives that the lateral displacement of the axles influences tyre wear?*

Question 21. — *Have you proved that lessening of hunting (particularly lessening the rotation of the bogie round its pivot) reduces tyre wear?*

No Administration has carried out any systematic enquiry on the repercussion on the wear on the tread of the possible lateral movement of the axle.

Question 22. — *Have you tried or do you use independent wheels? What has been your experience with these wheels regarding tyre wear?*

No test of independent wheels on locomotives has been reported.

D. AXLE BOXES.

a) **Roller bearing boxes.**

Question 23. — *Do you use roller bearings? If so, kindly say what results have been obtained regarding :*
a) *Number of hot boxes;*
b) *Maintenance costs;*
c) *State period between lubrication and inspection.*

Question 24. — *Have you found any difficulties due to the use of axle boxes of this type? Please indicate (fractures and wear of details, damage through rough shunting, etc.).*

Three Administrations (S. N. C. B., S. N. C. F., Netherlands) report experience with roller bearing boxes on locomotives.

Their replies are summarised as follows :

Number of hot boxes. — The extremely rare cases are quoted as due to fracture of the rings, loosening of the wedge rings, or wear of the boxes (S. N. C. F.). The Netherlands Railways state that in three years there have been seven cases of heating on the 4-6-0 locomotives of class 4000 (150 boxes) and two on the 0-8-0 locomotives of class 4700 (280 boxes) which locomotives have roller bearing boxes throughout.

Cost of maintenance. — The S. N. C. B. has not given any comparison with the ordinary box and bearing and only mentions an inspection every 50 000 km requiring 0.40 man hours and 0.250 kg of grease.

The *Netherlands Railways* say that so far as they are concerned the costs of repairs cannot be determined closely but at present are lighter than for axle boxes with plain bearings due probably to certain damage (corrosion) mentioned later on.

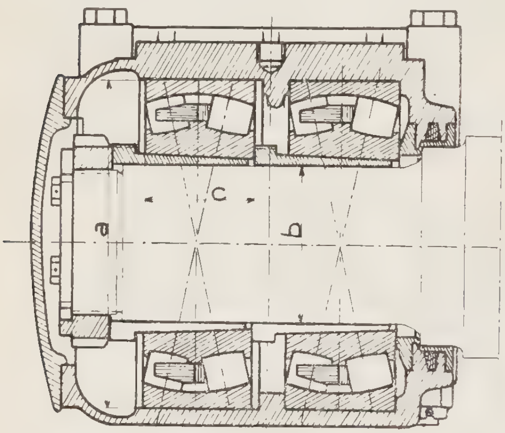

Fig 1. — S. K. F. roller bearing axle box of the outside type with double lines of rollers, held on the journal by split conical bush.

The *S. N. C. F.* has made an interesting comparison based on the 1 323 locomotives of the 2-8-2 R type put into service in 1945-47 and only differing by the type of *driving axle boxes,* namely :

A. — 700 engines with boxes with plain bearings.

B. — 400 engines Timken roller bearings on the driving axle and plain bearings on the others.

C. — 223 engines with Timken roller bearings on all coupled wheels.

All the above locomotives have roller bearing axleboxes on the carrying wheels.

The comparison was done by collecting from the depots using those engines for the six months (1-1-49 to the 30-6-49) the number of wheels dropped in current service for all reasons (over-heating, inspections, etc.).

Table 6 shows that no axles were dropped in the period considered when fitted with roller bearings. Fitting roller bearing axle boxes to the driving wheels alone reduced considerably the number of times axles had to be dropped on the engine and is in itself an effective measure to increase the period between repairs.

Frequency of lubrication.

The *S. N. C. B.* lubricates with grease (S. K. F. boxes) : at the inspection at 50 000 km the grease is renewed (consumption 250 g per box inspected).

The *S. N. C. F.* lubricates the S. K. F. boxes with grease and the Timken with oil :

— bi-monthly the lubricant is filled up;
— at each lift (500 000 km) the oil is emptied out without taking down the roller bearings;
— at each general repair (or at 500 000 km) all bearings are taken down and the body of the axle inspected.

Netherlands Railways — grease (S. K. F. boxes) :

— monthly : 200 g of new grease added;
— general repairs : boxes inspected.

Disadvantages.

The S. N. C. B. only reports a few cases of heating due to the breaking of the races but these heating cases are extremely rare.

The Netherlands Railways report corrosion : necessitating the renewal of the bearings on the driving axles at each General Repair (81 % of the replacements). They point out that this difficulty was due to leakage of water from steel fire boxes and made it necessary to use a special grease (*Shell B. C. 160* grease of a

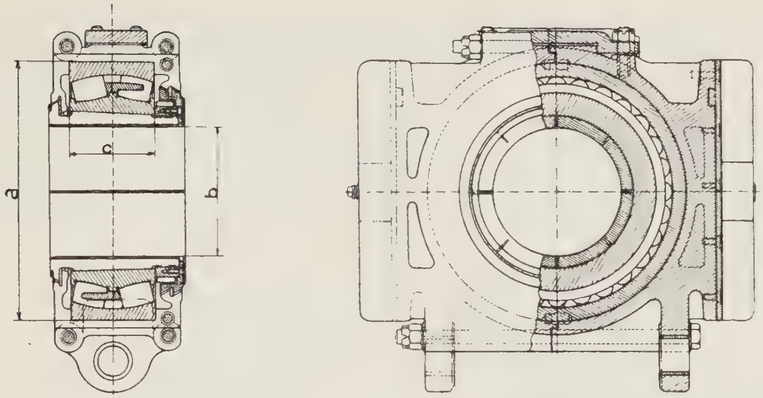

Fig. 2. — S. K. F. inside type single bearing with double row of rollers forming a spherical bearing held on the journal by a split coned sleeve.

Ca-Ba base mixed with an anti-corrosive paste). This Administration reports broken races.

The S. N. C. F. has also found corrosion on certain of its 2-8-2 R locomotives when first put into service but this was due to an unusual cause (introduction of sea water or moist air during transport by sea) and disappeared after the boxes had been overhauled. Generally speaking the S. N. C. F. states there are no disadvantages with these boxes.

Question 25. — *What type of roller bearing box do you use (cylindrical, conical or roller bearings)?*

Table 7 gives the application of roller bearings to the steam locomotives of the different Administrations.

Question 26. — *What type of protection do you use against the penetration of dust and water into the interior of the box?*

a) *S. K. F. boxes.*

These grease lubricated boxes are generally sealed with a merino felt ring in a groove in the box rubbing on a collar gripped on the axle (fig. 5) or by a system of grooves and projections forming a labyrinth (fig. 6).

The Netherlands Railways state, after trials on tenders, that the double bearing boxes are more effectively sealed than those with single races. The applications reported by the S. N. C. B. and S. N. C. F. are mainly S. K. F. double bearing boxes.

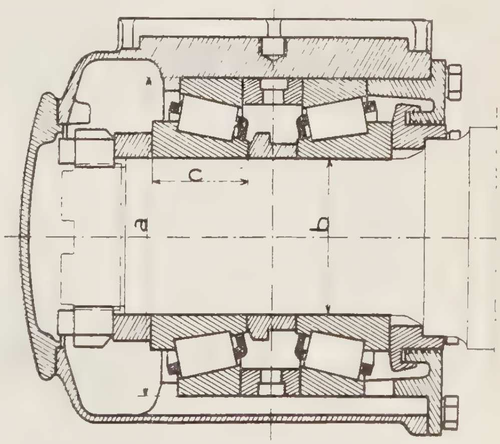

Fig. 3. — Timken taper roller bearing box of the outside type with two bearings each with a single row of rollers shrunk onto the journal.

TABLE 6.

Running repairs of coupled axles of the S. N. C. F. 282-R locomotives.

Types of boxes on the coupled axles of the locomotives	Number of locomotives	Mileage run from 1-1-1949 to 30-6-1949 in km	No. of times axles concerned dropped	
			Roller bearing boxes	Ordinary (oil) boxes
A) 282 R locomotives with boxes with brasses on all coupled axles . . .	700	22 314 000	»	401
B) 282 R locomotives with roller bearing boxes on the driving axle and ordinary boxes on the three other coupled axles	400	14 580 000	0	46
C) 282 R locomotives with roller bearing axle boxes on all coupled axles	223	9 716 000	0	»

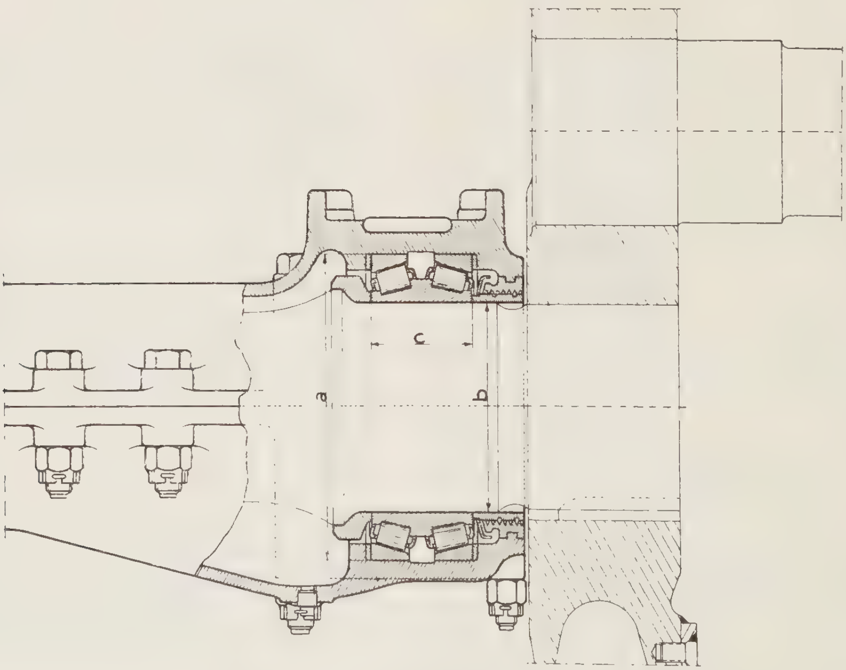

Fig. 4. — Timken taper roller bearing of the inside type with single bearing with two rows of rollers shrunk on the journal (canon type box on the driving axles of the S. N. C. F. 2-8-2-R locomotives).

TABLE 7.

Application of roller bearing axle boxes to steam locomotives.

Administration	Types of boxes used	Types of locomotives and axles to which applied	Number of	
			Locomotives or tenders fitted	Boxes
BELGIUM. *S. N. C. B.*	— SKF inside box with one double set of rollers diag. fig.2.)	Bogie of express locomotives types 1 and 2.	—	228
	— SKF outside box with two bearings each with two rows of rollers (diag. fig. 1)	Bissel truck of type 1 locomotives. Tenders of type 1 locomotives.	15	120
FRANCE. *S. N. C. F.*	— SKF outside boxes with two double sets of rollers (diag. fig. 1).	Leading truck of 484 A1 locomotives.	1	2
		Bogie truck of 464, R, S, U. locomotives.	4	32
	— SKF inside boxes with one double set of rollers (diag. (fig. 2).	Tenders 32 P, 34 P, 34 X, 22 C.	371	2 968
		Driving and coupled axles of 464 U locomotives.	1	6
		BP driving axle and bogie of 480 P locomotives.	2	12
	— *Timken* outside boxes with two bearings each with single set of tapered rollers (diag. fig. 3).	Leading truck of 282 R loc.	1 323	2 646
		Bogie and truck of 464 R, S, U, locomotives.	4	32
		Tenders 34 P, 30 R, 22 A, B, C.	775	6 200
	— *Timken* inside boxes with one bearing with double row of tapered rollers (canon type box) (diag. fig. 4).	Driving and coupled axles of 282 R locomotives,	623	4 984
		AV Bissel truck 282 R locom.	1 323	2 646
		Bogie of 484 A1 locomotive.	1	4
		Bogie of 462 D, F, G, locomot.	69	276
NETHERLANDS. *Netherlands Rys.*	— SKF inside boxes with one double set of rollers (diag. fig. 2).	Bogie, driving and coupled axles of type 460, 4 000 class locomotives.	15	150
	— SKF outside boxes with one double set of rollers (diag. fig. 2).	Driving and coupled axles of type 080, 4 700 class locomotives.	35	280
	— SKF outside boxes with two double sets of rollers (diag. fig. 1).	Tenders of 460 and 080 type locomotives above.	50	400
		4-axle tenders fitted in 1932.	1	8

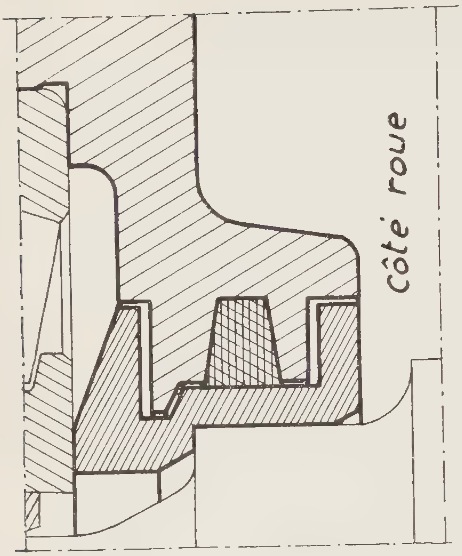

Fig. 5. — Arrangement of felt dust ring used on S. K. F. boxes of the outside type with grease lubrication.

Explanation of French terms : Côté roue = Wheel side.

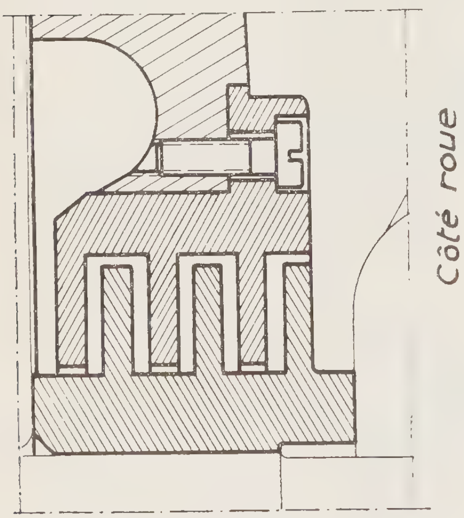

Fig. 6. — Labyrinth seal on the outside type S.K.F. boxes with grease lubrication.

Explanation of French terms : Côté roue = Wheel side.

b) *Timken boxes.*

On the Timken oil boxes a deflector secured to the axle tends to throw the oil, by centrifugal force, into the inside of the box. The box cover on the deflector side is made with several circular grooves on the face forming the joint with the axle (fig. 7).

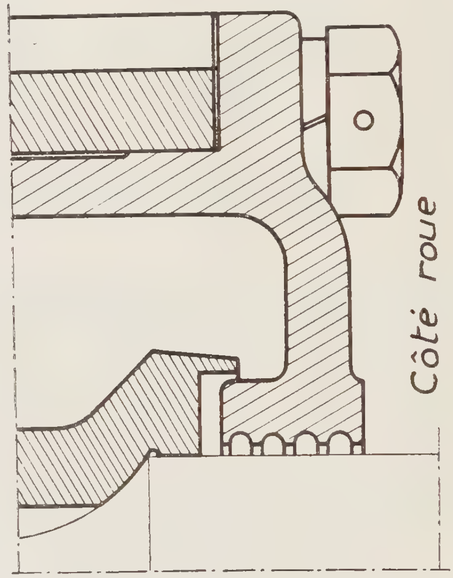

Fig. 7. — Timken outside type oil lubricated roller bearing axlebox with seal by means of a thrower and circular grooves.

Explanation of French terms : Côté roue = Wheel side.

Question 27. — *What are the loads per axle and the speeds permitted for the boxes you use? Give principal dimensions, catalogue number, drawing, etc.?*

Table 8 gives the information this question asked for.

Question 28. — *What is the system of mounting the rollers on the journal? What are the advantages and disadvantages of the system used?*

The different types of fastening the roller bearings on the axle are :

— *S. K. F.* roller bearings in most cases (inside or outside types) are held by a split coned sleeve (fig. 1) except in rare applications where the bearing is fitted directly on the journal for lack of space;

— *Timken* bearings are generally pressed onto the journal : in the most recent patterns the bearing is secured by taper sleeves held by a lock nut from the axle end;

— fastening by split taper sleeve does not require quite so accurate machining of the journal and makes it possible to inspect and take down the bearings without damaging the journal. The direct fastening also involves the use of a press (S. N. C. B., S. N. C. F.).

The Railways consulted favour the fastening with sleeve.

Question 29. — *Do you use special arrangements to prevent electric current passing through the roller bearings (current for traction or heating)?*

No Railway consulted uses any such device.

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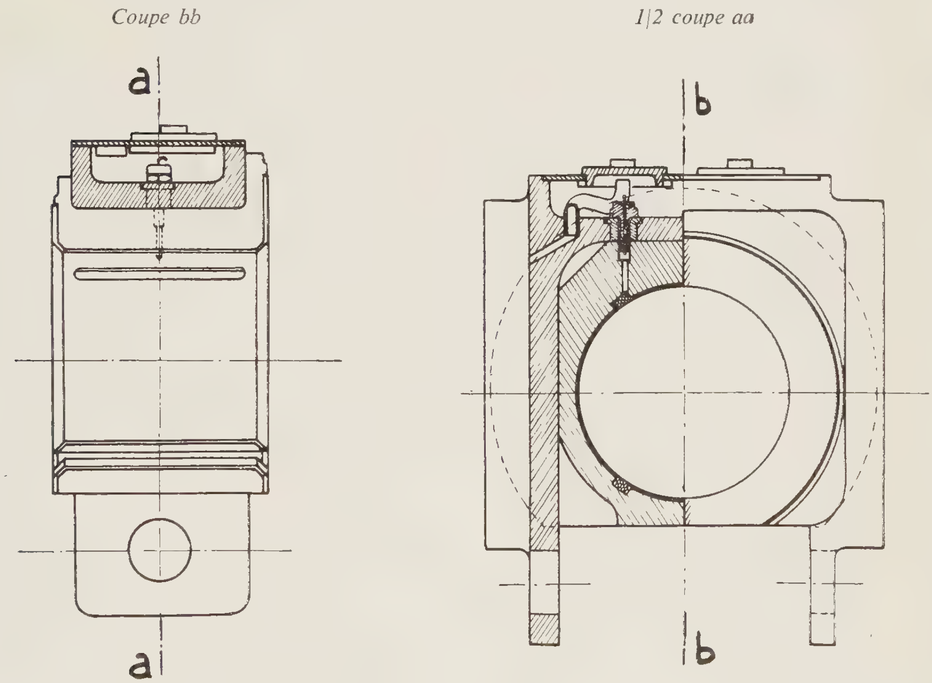


Fig. 8. — Box with brass enveloping the journal and with vertical joint without oil well and oil lubricated by the general mechanical lubricator (S. N. C. F.).

B. — AXLEBOXES WITH PLAIN BEARINGS OTHER THAN THE ORDINARY BOXES WITH PADS OR PACKING.

Question 30. — *Describe what types of axle boxes having bearings or brasses other than ordinary axle boxes do you use?*

TABLE 8.

Particulars of the different types of roller bearing used in the roller bearing axle boxes.

I. — S. K. F. roller bearing boxes (classed by diameter of journal in increasing order).

Catalogue denomination (1)	Number of bearings per box	Projected length of the bore of the inside ring in mm	Outside diameter of the outside ring	Minimum diameter (2) of the bore of the inside ring in mm	Administration and description of the stock		Diameter of the journal in mm	Wheel diameter in mm	Maximum speed of the vehicle in km/h	Maximum axle load in t.
I 37 906	2	86	260	130	Tenders 34 X	S. N. C. F.	120	1 000	80	18.3
					Tenders 22 C	S. N. C. F.	125	960	120	15
I 37 604	2	86	260	140	Tenders 22 C application being studied	S. N. C. F.	135	960	120	15
I 37 605	2	93	280	150	Tender 3927	Netherlands Railways	140	1 100	110	16
23 330K	2	108	320	150	Tenders of locomotive type 1	S. N. C. B.	140	1 000	140	20.8
22 332K	2	114	340	160	Bissel of loc. type 1	S. N. C. B.	150	1 065	140	21.5
I 37 606	2	102	300	160	Bogies and bissels of loc. 464 R.S.U.	S. N. C. F.	150	970	120	16
					Bissel of loc. 484 A 1	S. N. C. F.	150	1 110	120	15
I 37 607	2	108	320	170	Tenders 32 P	S. N. C. F.	150	1 110	120	20
					Tenders 34 P	S. N. C. F.	150	1 247	120	22
22 334K	1	120	360	170	Tenders of loc. 460 and 080 (series 4000 and 4700)	Netherlands Railways	160	1 080	120	13.2
22 336K	1	126	380	180	Bogie of loc. 480 P	S. N. C. F.	170	960	120	16.8
22 336	1	126	380	180	Bogies of loc. type 1	S. N. C. B.	180	900	140	16.2
					Bogies of loc. type 12	S. N. C. B.	180	900	140	12
I 26 308	1	114	340	180	Bogie of loc. 460 series 4000	Netherlands Railways	180	980	120	14.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Coupled axles of loc. [illegible]	Netherlands Railways	240	1 890	120	18.3

23 152	1	144	440	260	Driving axle BP of loc. 480 P	S. N. C. F.	260	1 850	120	20
					Driving axle of loc. 460 series 4000	Netherlands Railways	260	1 890	120	18.3
					Driving axle of loc. 080, series 4700	Netherlands Railways	260	1 350	70	18.5

II. — TIMKEN (3) tapered roller bearing boxes.

154103 X /154531	1 double	81	262	135	Tenders 22 A, B, C	S. N. C. F.	135-130	960	120	15
450589 X /451201X	2 singles	89	305	150	Tenders 34 P	S. N. C. F.	150	1 247	120	22
451201 X /450590X	1 double	93.5	305	150	Bogie and bissel of loc. 464 R, S, U	S. N. C. F.	150	970	120	16
99603 /99100	2 singles	66.5	254	154	Tenders 30 R	S. N. C. F.	154	1 067	90	18
560950 /561251	2 singles	78	317.5	165	Bissel AR of loc. 282-R	S. N. C. F.	165	1 067	90	19
280569X /281201X	1 double	149.5	305	170	Bogie loc. 484 A1	S. N. C. F.	170	970	120	17
281201X /280669	1 double	148	305	170	Bogie loc. 462 D, F, G	S. N. C. F.	170	960	120	13
470975 /470131	1 double (canon type box)	82.5	336.5	190.5	Bissel AV loc. 282-R	S. N. C. F.	190.5	914	90	17
M 244649 D/M 244610	1 double	127	336.5	219	Coupled axles of locomotives 282 R	S. N. C. F.	219	1 650	90	20
M 552849 D/M 552810	1 double	130	392	270	Driving axle of loco. 282 R	S. N. C. F.	270	1 650	90	20

NOTE (1) The bearings with classification numbers ending with letter K, and those beginning with letter I are bored out conically and secured by a tapered sleeve. The other bearings are bored cylindrically and mounted hot on the journal.

(2) When the bore is tapered.

(3) The Timken bearings for locomotives and tenders are bored cylindrically and fitted hot on the journal.

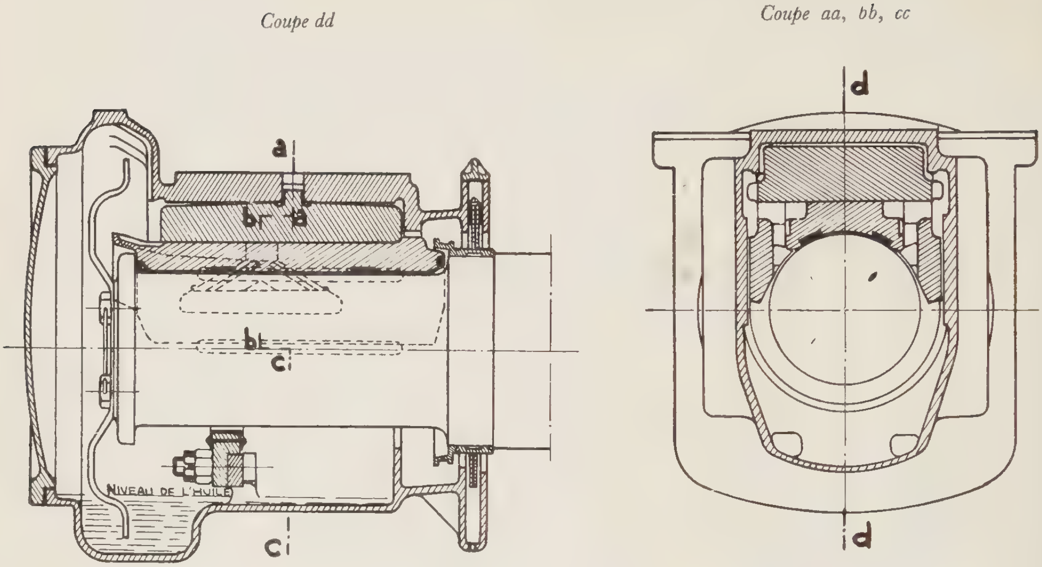


Fig. 9. — Athermos box with the oil circulated by a paddle secured to the end of the axle (S. N. C. F. tenders).

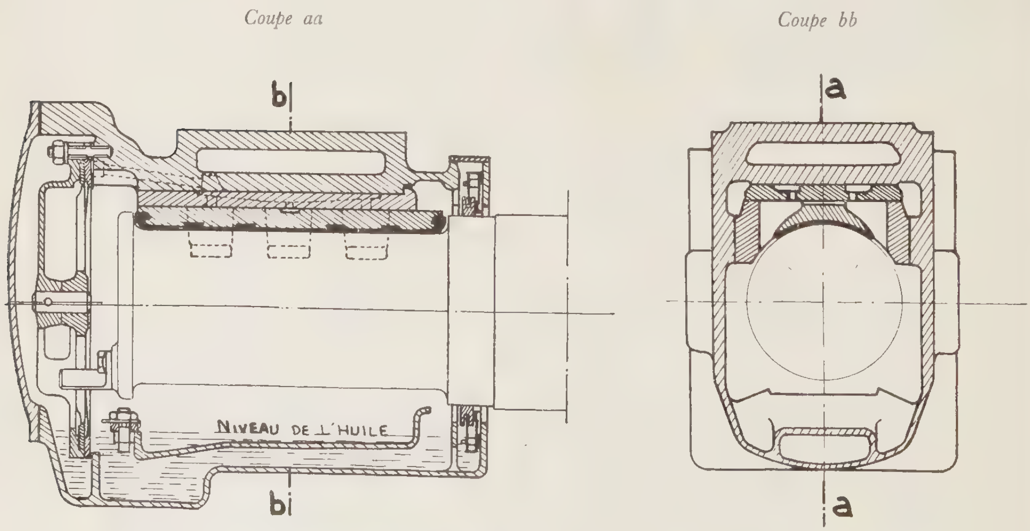


Fig. 10.—Stemi-Friedmann box with bearing lubricated by oil circulated by a disc (S. N. C. F. tenders).

Explanation of French terms : Niveau de l'huile = Level of oil.

Question 31. — *What is used for the lubrication of these axle boxes (grease or oil)?*

Besides the ordinary plain bearings the use is mentioned of :

a) boxes with brasses enveloping the journal, without pads, lubricated from a lubricator under pressure;

b) boxes known as oil circulating boxes.

a) *Enveloping bearing with vertical joint (S. N. C. F.).*

A brass in two parts *surrounding the axle completely and with a vertical joint,* lightly pressed into the box and under trial on driving axles. This bearing (fig. 8) is provided with 4 felt oiling pads, two at the bottom and two at the top, these latter being fed with oil from a mechanical lubricator forming the only way the bearing is oiled ; there is no keep (and therefore no reserve of oil) and no dust shield. The white metal is a thin layer. After satisfactory results obtained on freight and average speed trains the trial has been extended to high speed trains. The S. N. C. F. report that on the crank axles of the Sud-Est high speed locomotives of the 462 type the mileage between axle-box repairs has been doubled and even trebled by the use of these new boxes.

b) *Oil circulating boxes.*

Three types of such boxes are used :

— *Isothermos;*

— *Athermos;*

used by the S. N. C. F., S. N. C. B., Norwegian Railways (Peyinhaus box), Algeria, Moroccan, Damas - Hama, Indo-China Railways;

— *Stemi-Friedman :* used by S. N. C. F.

In the *Isothermos* as in the *Athermos* the oil is deflected or thrown onto the top of the bearing by a paddle picking up the oil fastened to the end of the axle (see fig. 9), the second type only differing by the fitting of a small bearing under the journal to prevent the bearing accidently getting on to the end of the journal in case of shock.

In the *Stemi* box (fig. 10), the oil is picked up by a disc carried by a pin secured to the box and driven by a pin fastened to the end of the axle.

In all these boxes the oil thrown onto the top of the brass flows through passages and grooves to the face of the journal.

These boxes are all lubricated by oil.

Question 32. — *What type of protection is used against the penetration of dust and water to the interior of these axle boxes?*

a) *Boxes with bearings surrounding the journal and with vertical joints.*

The box has no dust shield as it has no oil reservoir.

b) *Boxes with oil circulation.*

The prevention of the penetration of dust and water into the *Athermos* box is assured by a centrifugal thrower secured to the axle and intended to throw back the oil by means of the classic type of disc thrower (figs. 9, 11, 12).

In the *Stemi-Friedmann* box a dust shield is fitted (figs. 10 and 13).

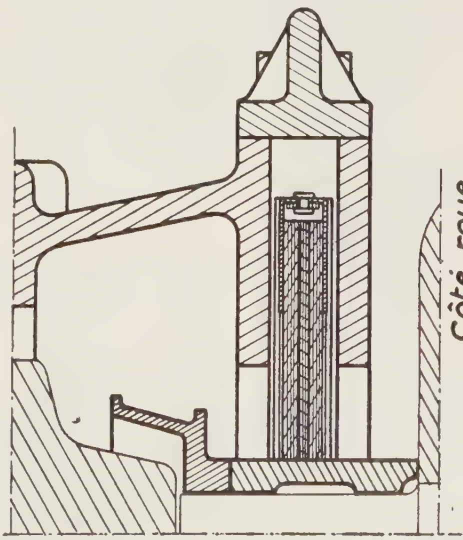


Fig. 11. — Dust shield on *Athermos* boxes (S. N. C. F. tenders).

Explanation of French terms : Côté roue = Wheel side.

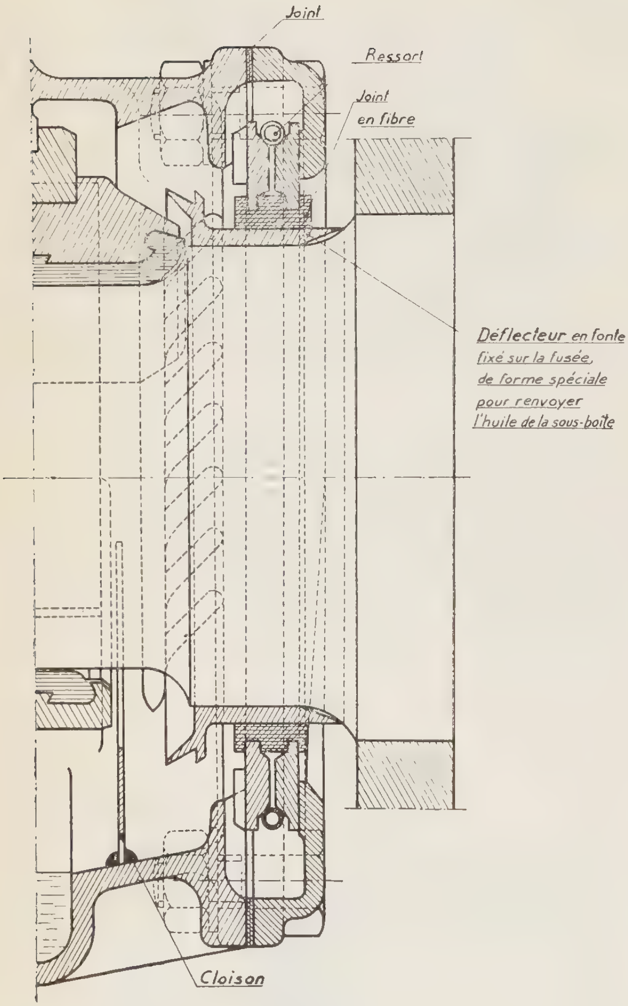


Fig. 12. — *Isothermos* box dust shield (C. F. F. coaches) (taken from C. F. F. drawing 12184).

Explanation of French terms :

Joint = Joint. — Ressort = Spring. — Joint de fibre = Fibre joint. — Déflecteur en fonte fixé sur la fusée, de forme spéciale pour renvoyer l'huile de la sous-boîte = Cast iron thrower fastened to the journal of special shape to throw back the oil from the under base. — Cloison = Wall.

C. — IMPROVEMENTS TO ORDINARY AXLE BOXES WITH BEARINGS AND BRASSES.

Question 33. — *What improvements have you carried out to brasses and oil pads?*

Various improvements are reported :

White metalling the sides of the bearings.

The Netherlands Railways point out the value of reducing the friction between the box and the wheel centre and report that since 1933 they apply white metal on the face of the axle box nearer the wheel boss. The S. N. C. F. also report using anti-friction metal in this way.

Bearing in the form of a thin shell.

The S. N. C. F. is testing the *Augereau* arrangement (fig. 14) originally designed to save bronze. The box is of the American

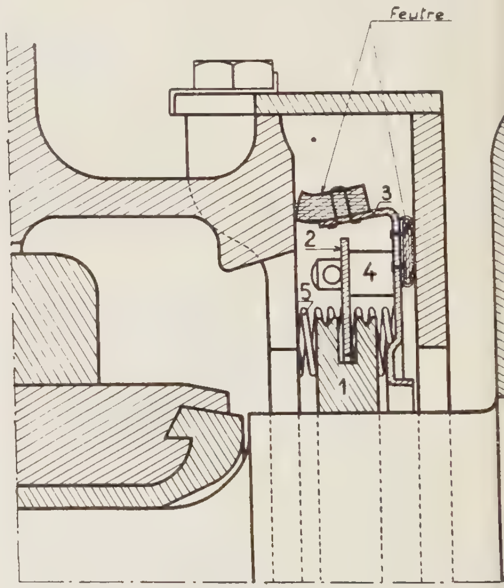


Fig. 13. — *Stemi-Friedmann* dust shield : .1. Revolving ring to throw the oil. — 2. Division. — 3. Fixed frame to deflect the oil thrown off it and seal. — 4. Pin carrying the division. — 5. Spring holding the frame in place.

Explanation of French terms :

Feutre = Felt. — Côté roue = Wheel side.

type but the usual bronze bearing in it is replaced by a shell 8 mm thick which has had a 2 mm thick layer of white metal applied centrifugally. A driven key holds the shell from turning: in addition two checks studded on the box prevent the

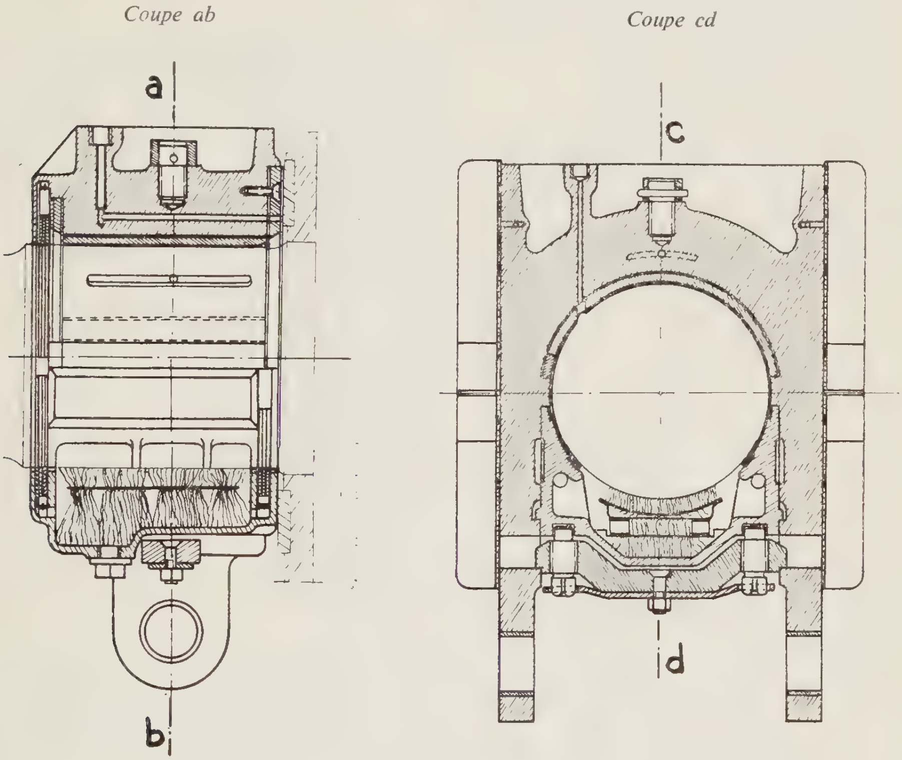


Fig. 14. — Steel axleboxes with bronze shell Augereau system.

shell moving sideways. The tests have been satisfactory. Although there is no longer the same shortage of bronze as during recent years, the S. N. C. F. continues to test this type of bearing on certain groups of locomotives. The value of this bearing is that the shell can be replaced quickly from stock details machined to dimensions either standard or standardised.

Oil ways.

The S. N. C. B. reports that its bearings are being replaced progressively by bearings with two grooves at 60° on each side of the vertical centre line. The angle used by the S. N. C. F. differs sligthly, being 45°.

Dimensions of the bearings:

The Netherlands Railways report from their experience of the 280 and 2-10-0 locomotives acquired since the war that it is advisable to use in the following equation:

$$\frac{\text{total weight} \times \text{peripheral speed}}{\text{projected area of the bearing}}$$

a value of the order of 3 000 (on the 280

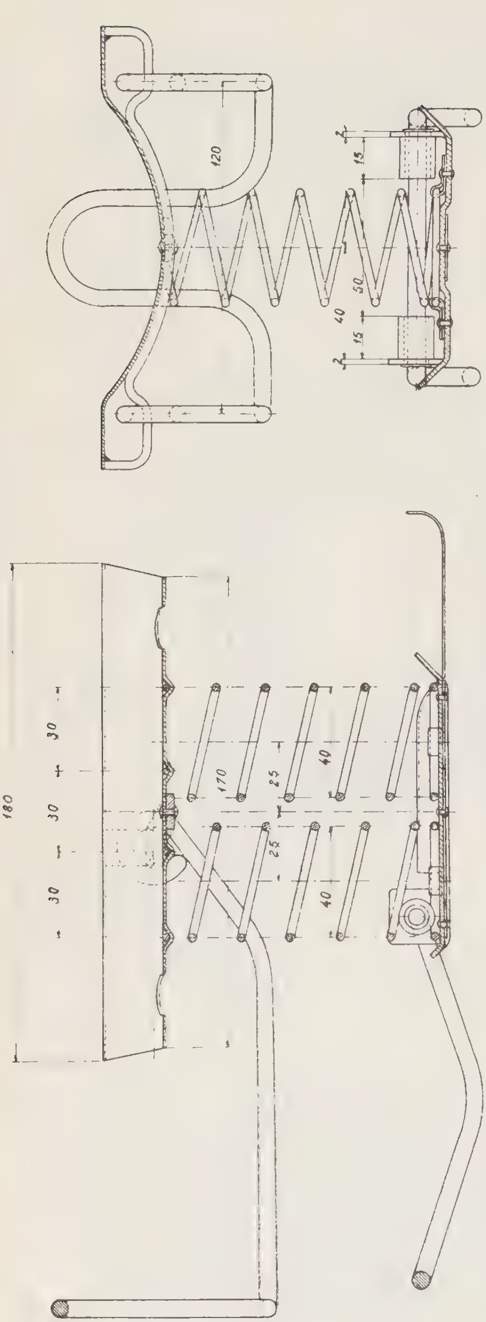


Fig. 15. — Lubricator frame used by the Netherlands Railways to apply the packing against the journal (from the Netherlands Railways Drawing V. 5147).

in question the value is 2 430 for the driving wheels and 2 630 for the coupled wheels) instead of the value of 4 500, that this Administration gives for its other goods engines. It ascribes to this reduction the increase in mileage between two successive repairs which has risen from 80 000 km to 120 000 km for these locomotives.

Lubricator pads.

On the S. N. C. F., it has been found that lubricators with laminated springs are better than those with coiled springs. In addition, to improve the ascent of the oil towards the journal the present tendency is to use for the part immersed in the oil, wicks of half wool and half cotton the capilliarity of the cotton being the better.

The S. N. C. B. prefers packed boxes as simpler. The same tendency is found in the Netherlands Railways on which an intermediate solution is used with the packing pressed against the journal by a coiled spring lubricator frame (fig. 15).

On the Gafsa Railways where the lubrication of the journals is very delicate owing to the violent sand storms experienced in these regions, tests of lubrication with stiff grease introduced under pressure by a *Tecalemit* lubricator have given good results.

Question 34. — *What type of anti-friction alloy is used? Is there a preference for the use of anti-friction metal rich in tin, according to the type of vehicle (load and speed)?*

Table 9 gives the name and composition of the white metals used on the steam locomotives, according to their weight or speed and also the method of applying the white metal and its thickness.

Question 35. — *Describe the method of applying the anti-friction metal (grinding, centrifugal, sintering, fritting, etc.) and the minimum thickness of the layer.*

Table 9 gives the method of applying and the thickness of the white metal. The

method of application is usually in a mould or by pouring. The S. N. C. F. also in some works uses centrifugal casting. « Frittage » is not reported on any instance as in use. As regards the thickness of white metal the general tendency is to reduce it without going below 5 mm.

D. — PRESENT PRACTICE IN THE CHOICE OF THE TYPE OF BOX.

Question 36. — *Set out the different categories of locomotives and rolling stock, and the various types of service which govern the choice of the type of boxes to be adopted, showing the reasons.*

It is still difficult to reveal any unanimous tendency in the choice of axleboxes but we note the extension of the use of roller bearing axleboxes on new stock recently built.

The satisfactory results reported by the S. N. C. F. favour the use of roller bearing axleboxes not only on carrying axles of passenger and freight locomotives but also on coupled axles (and even on the driving axle alone). The S. N. C. B. recognise their value for high speed stock. The Netherlands Railways to not appear to have given any decision : they draw attention none the less to the fact that their locomotives with ordinary bearings reach the limit of wear allowed in the bearings before the maximum allowed hollow wear of the tread of the tyres is attained. They point out that this is not so with roller bearing boxes. This Administration points out that in the case of its 4-6-0 type 4000 locomotives with roller bearings and adjustable wedges it has increased the mileage between two general repairs from 100 000 km to 160 000 km.

It appears that a wide use of roller bearing axle boxes is still in certain cases linked with the question of making the axle boxes water tight. The Gafsa Railways in this connection hope that roller bearing boxes perfectly tight against sand may be developed.

The Danish, Luxemburg and Norwegian State Railways state that they continue to use boxes with brass bearings.

Valuable improvements have been made to boxes with brasses (brasses surrounding the journal divided on the vertical centre line of the S. N. C. F., the *Athermos* and *Stemi* boxes with continuous circulation of the oil over the outside journals).

E. — WEARING AND FRICTION METALS.

Question 37. — *What are the details, in your opinion, the wear of which limits the mileage between repairs?*

The replies received agree in considering that apart from the tyres the details the wear of which limit the mileage between repairs are :

- — pinned joints in the valve and spring gear;
- — guides or slides of axleboxes;
- — axlebox bearings (lateral and longitudinal play);
- — piston rings.

The Netherlands Railways in particular point out that the maximum allowable play in boxes with brasses develops more quickly than the wear of the tyres. By fitting roller bearing axleboxes, this Administration has been able to increase the mileage of its 4700 class locomotives.

Question 38. — *What materials are used to reduce the wear of details subjected to friction (axle box guides, various joints, etc.).*

a) *Axle box guides.*

Table 10 gives particulars of the materials used for axlebox guides. The extended use of manganese steel sliding on the same material should be noted.

A method of taking up the play between the guides and the boxes is the use of *self-adjusting* wedges used on the S. N. C. F. steam locomotives (American wedges of the Franklin type with which the S. N. C. F. is satisfied). The Netherlands Railways

T

Nature of white m

ADMINISTRATION	Description of the anti-friction metal	Con	
		Sn %	Sb %
BELGIUM. *S. N. C. B.*	M1 M3	83 5	11 15
Bas-Congo to Katanga Railways	—	5	10
Matadi to Léopoldville Railway	High tin white metal	—	—
DENMARK. *State Railways*	—	80	15
FRANCE. *S. N. C. F.*	AE3	78	13
Gafsa Railway	AE2	80	12
Algerian Railways	AE1	—	—
Moroccan Railways	AE3	78	13
Damas-Hama and extensions Railway	—	80	12
Indo-China Railways	AP2	5	10
Soc. Gén. des Chemins de fer Economiques (meter gauge)	AE3	78	13
NETHERLANDS. *Netherlands Railways*	—	81.5	10
LUXEMBURG. *Luxemburg Railways*	High tin metal AE 83 AE 60	—	—
NORWAY. *State Railways*	Standardised alloy	83	12
SWITZERLAND. *C. F. F.*	—	80	13

bearings.

Ph %	Cd %	Method of application and thickness of white metal	Use and remarks
— —	— —	Moulded 5 mm thick —	Road locomotive speed $\geqslant$ 90 km/h. Other locomotives.
—	—	—	—
—	—	Moulded 8 to 10 mm	—
—	—	Moulded thickness 10 mm max.	All locomotives. Above this thickness, the old metal breaks.
—	—	Moulded usual thickness 4 mm	Express locomotives and those with axle loads exceeding 17 t. During repairs the thickness of white metal increases.
0.3	—	Moulded minimum thickness 10 mm	Tests with alloys with less tin have not given good results.
—	—	Moulded minimum thickness 4 mm	Locomotives and tenders of all classes.
—	—	Moulded.	All motor stock.
0.3	—	Moulded 6 mm	Locomotives.
—	—	Moulded 5 to 8 mm	All stock.
—	—	Moulded 5 mm	All locomotives.
—	—	Moulded 8 to 10 mm	All locomotives.
—	—	Moulded minimum thickness 3 to 5 mm	Driving and coupled axle boxes of heavy powerful locomotives. Carrying-axle boxes of locomotives above, and all axles of other locomotives.
—	1	Moulded minimum thickness 5 to 6 mm	All locomotives (boxes and rods).
—	—	Moulded minimum thickness 5 mm	All locomotives. Tests with other alloys have not succeeded.

TABLE 10.

Metals on rubbing surfaces used for axle box guides.

ADMINISTRATION	Kind of metal guide — face of box	Remarks
BELGIUM. *S. N. C. B.*	not stated — bronze { Sn 11 % Ph 0.3 % Cu 88.7 %	—
FRANCE. *S. N. C. F.*	Cast iron — Steel Bronze — Hardened steel Manganese steel — Manganese steel	Being applied generally. Under test gives better results than the previous couple of metals.
Gafsa Railways	Steel with 13 % manganese — Steel with 13 % manganese	Satisfactory results.
Indo-China Railways	Case hardened steel — Case hardened steel	
Damas-Hama and extensions Railways	Phosphor bronze — not stated	
Société Générale des Chemins de fer Economiques (meter gauge)	semi-hard steel — not stated	
LUXEMBURG. *Luxemburg Railways*	Steel ARBED SEMI MANAX to 90 kg/mm² — Bronze ARBED 40/40 to 40 kg/mm²	Tests have given satisfactory results. General application considered.
NORWAY. *State Railways*	Bronze — Not stated	

TABLE 11.

Metals used for pinned joints.

Administration	Type of articulation	Kind of metal of the bush	Kind of metal of the pin (or the spring seat)	Remarks
BELGIUM. *S. N. C. B.*	— Motion	Bronze : Sn 11 % Ph 0.3 % Cu 88.7 %	Steel	
	— Brake and spring gear	Case hardened and tempered steel	Case hardened and tempered steel	
Matadi to Léopoldv. Railway (OTRACO)	All joints	Tempered steel	Tempered steel	
FRANCE. *S. N. C. F.*	— Motion	Hard bronze	Mild steel at 37 kg/mm² case hardened and tempered	Joints have the bushes fixed on the pin turning
	— Brake gear	Steel at 65 kg/mm²	— ditto —	
	— Suspension (equalisers, etc.)	— ditto —	— ditto —	
Société Générale des Chemins de fer Economiques	All kinds of joints	Case hardened and tempered steel	Case hardened and tempered steel	
Moroccan Railways	Suspension	Not specified	Case hardened steel	
LUXEMBURG. *Luxemburg Railways*	Motion	Bronze	Case hardened steel	
NORWAY. *State Railways*	Motion	Steel	Steel	
	Brake rigging	Steel	Steel	

as regards the value of adjustable wedges called attention to the mileages obtained with their 460 class 4000 and 0-8-0 class 4700 locomotives.

b) *Pinned joints.*

Table 11 gives the metals used in pinned joints (pins and bushes). The general arrangement adopted is bronze bushes and case hardened and tempered steel pins.

Question 39. — *What methods have you adopted to make good worn details (e. g. fitting washers or bushes at joints, using easily replaceable wearing portions, etc.)?*

The replies to questions 37 and 38 show the use of readily renewable liners and the use of bushes in the joints.

These liners are almost always secured in position on the parts to be protected by welding or by welding and rivetting. A method frequently used to fasten axlebox liners in conjunction with continuous or intermittent welding of the edges of the liner is plug welding. This method consists in drilling a certain number of holes in the liner and filling these holes by welding. Fig. 16 show manganese steel liners as fastened by the S. N. C. F.

Question 40. — *Have you adopted any special arrangements to avoid reciprocal friction between the different details (e. g. guiding by articulated links on silent block, etc.)?*

No special devices such as silent blocks have been reported on steam locomotives.

Question 41. — *Do you use with spring suspension details any protection devices on the parts subjected to friction (supports for the adjusting spring links, buckles, etc.)?*

The use of liners has not been reported the wear being overcome by the hardness of the spring hanger bearing plate (generally in manganese steel) or by the fine grain steel of the spring equalisers (cast carbon steel).

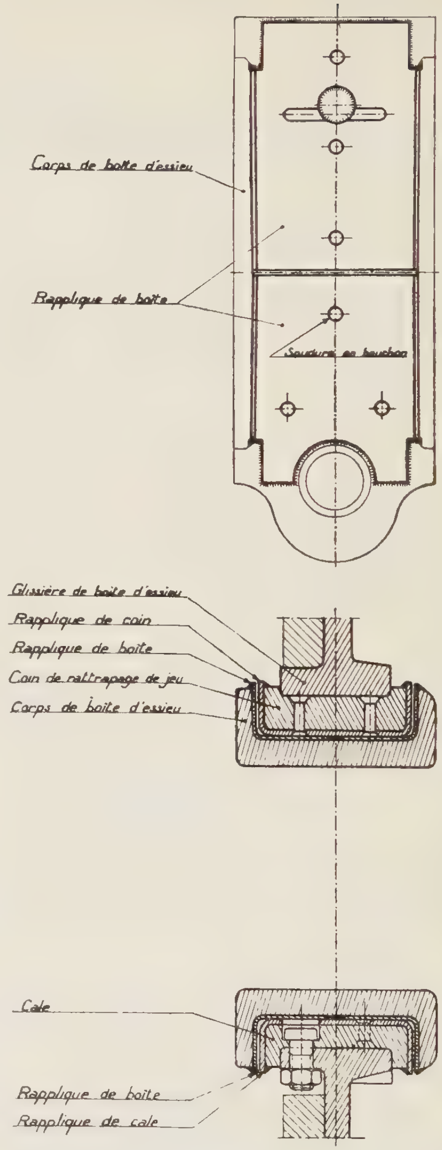


Fig. 16. — Renewable liners to take up wear in manganese steel on the guides and bodies of axle boxes S. N. C. F.

Explanation of French terms :

Corps de boîte d'essieu = Axle box body. — Glissière de boîte d'essieu = Axle box guide. — Rapplique de coin = Wedge liner. — Rapplique de boîte = Box liner. — Coin de rattrapage de jeu = Wedge to take up play — Corps de boîte d'essieu. = Body of box. — Cale = Wedge. — Rapplique de boite = Box liner. — Rapplique de cale = Wedge liner.

F. — SPRINGS.

Question 42. — *What methods have you adopted to lessen the number of spring failures (weakening, fractures, etc.)?*

a) *for laminated springs;*

b) *for spiral springs;*

c) *for volute springs.*

d) *for other types of springs (torsion bar, etc.).*

The locomotives springs are usually laminated. The most frequent damages are *slipping plates, loss of camber and breakage.*

Slipping plates.

The methods of overcoming this are given in the replies to questions 45 and 46.

Loss of camber.

To avoid loss of camber it is well to devote attention to the regular quality of the steel (question 43) and to make the springs large enough. The S. N. C. F. reports using the following formula for plate springs :

$$t = \frac{3\ Q\ L}{nbh^2}$$

in which L = half distance between the points at which the load is applied, in millimetres :

Q = total load in kilogrammes;

n = number of plates;

h = thickness of plates in millimetres.

The value of the fatigue « t » calculated in this way should not exceed 50 kg/mm² (31.75 t. per sq. inch.).

Fractures.

Fractures of the ends of the back plate have been reduced by using a bearing washer plate in place of rolled or forged ends (S. N. C. B., Netherlands Railways). Fractures due to the central hole have been reduced by the use of a pressed rocker plate (Netherlands Railways). The S. N. C. F. reports the use of shock absorber blocks of india rubber inserted between the springs and the axle boxes of the tenders.

Question 43. — *Are these failures brough about by the quality of steel, the design of spring, or manufacturing processes (state especially if you use oil or water hardening steels and the results obtained in each case; state quality of the steel used)? In those cases where the quality of steel is the cause, what arrangements have you adopted to ensure the consistent quality of steel? Attach specifications and state what steps you take to ensure the correct quality of steel being supplied.*

Table 12 gives the qualities of steels used to make plate springs. Of the six examples mentioned in the table, in four the metal is specified by its chemical composition (S. N. C. B., Netherlands, Denmark, Norway) whereas in the other two the control does not include any chemical analysis (S. N. C. F. and C. F. F.).

For a given heat treatment carried out during shop repairs it would appear that the method of imposing a definite composition would give a greater guarantee of consistency in the final result after treatment.

Question 44. — *Do you use special mounting arrangements in order to prevent movement not provided for (guiding, joints in the case of spiral springs, etc.)?*

No special arrangement has been reported.

Question 45. — *Are laminated springs buckles fitted hot or cold? State methods process and results obtained?*

There are two methods of putting in the spring buckles; hot buckling and cold buckling.

a) *Hot buckling.*

Other than the S. N. C. F. which is substituting progressively cold buckling in place of hot the replies from the Administrations only report hot buckling which, provided the pressure is suitable, gives satisfaction. The buckling tends to be done everywhere under a press. (The

QUALITY AND TREATMENT OF STEELS USED. — CONTROL C

TABI

Characteristics of the steels us

ADMINISTRATION	Nature and composition of the steel
BELGIUM. *S. N. C. B.*	Silico-Manganese steel (Technical Specification A-4-46). Composition % : C: 0.47 to 0.55; Si: 1.60 to 2.00; Mn: 0.50 to 0.80; P: 0.05 max.; S: 0.05 max.; P+S: 0.09 max. The steel is to be made in Martin, or Electric furnace or crucible.
DENMARK. *State Railways*	*Composition in % of spring steel* : C: 0.40 to 0.55; Mn: 0.50 to 0.75; Si: 1.50 to 1.80; P: 0.05 max.; S: 0.05 max.
FRANCE. *S. N. C. F.* Same regulations followed by : Algerian Railways. « Chemins de fer Economiques du Nord »; « Société Générale des Chemins de fer Economiques »; Damas-Hama Railway and extensions.	S steel (Technical Specification No. 8 C of the S. N. C. F.). No composition specified other than Phosphorus < 0.05 %.

Belgium — Composition % :

C	Si	Mn	P	S	P+S
0.47 to 0.55	1.60 to 2.00	0.50 to 0.80	0.05 max.	0.05 max.	0.09 max.

Denmark — Composition in % of spring steel :

C	Mn	Si	P	S
0.40 to 0.55	0.50 to 0.75	1.50 to 1.80	0.05 max.	0.05 max.

HE CONSISTENCY OF THE REQUIRED CHARACTERISTICS.

make laminated springs.

<table>
<tr><th>Heat treatment</th><th>Mechanical characteristics or required results of tests</th></tr>
<tr><td>Water hardened at 20° C after heating to 880° C.
Tempered at 475° C.</td><td>Tests :

1° Chemical analysis : if the percentages of C, Si or Mn are slightly outside the prescribed limits, appropriate physical tests are carried out before repeating the cast.
2° BAUMANN print : uniform shade.
3° Temper test : on test piece 200 mm, quenched and not reheated, with, on one side, a notch 5 mm wide and 3 mm deep. Not to show any crack after quenching. The fracture to be fine grain.
4° BRINELL hardness test and shock test : on a test piece quenched and tempered 200 mm long.
Hardness HB (load 3 000 kg, ball 10 mm) between 375 and 430.
Shock test: distance between supports 120 mm, trip of 50 kg height of drop $\frac{S}{4}$.
The test piece to stand at least 6 blows without cracking or breaking.</td></tr>
<tr><td>Water hardened at 50/60° C after heating to a temperature between 820° to 850° C. Tempered at 470° to 520° C. — Cooled in the air.</td><td>Mechanical characteristics required.

<table>
<tr><th></th><th>△
Brinell</th><th>R</th><th>E</th><th colspan="2">A %</th></tr>
<tr><td></td><td></td><td></td><td></td><td>$\frac{1}{d} = 10$</td><td>$\frac{1}{d} = 5$</td></tr>
<tr><td>before hardening</td><td></td><td>$\geqslant$ 85</td><td>—</td><td>$\geqslant$ 12</td><td>$\geqslant$ 14.4</td></tr>
<tr><td>After hardening and reheating</td><td>350 to 430</td><td>$\geqslant$ 140</td><td>$\geqslant$ 110</td><td>$\geqslant$ 5</td><td>$\geqslant$ 6</td></tr>
</table></td></tr>
<tr><td>Water hardened after heating to 850° to 900° C. Tempered at 450° C and cooled in calm atmosphere.</td><td>a) Test on bent plate 1 030 mm long and h mm thick :

1° Elasticity test.
A preliminary stabilising test for 5 minutes at a deflection equal to $\frac{1420}{h}$, defines, when the load is removed, the « original deflection », the deflection as manufactured being less than $\frac{1420}{h} + 40$.

A test under increasing load until the deflection reaches $\frac{1340}{h}$ and held under these conditions for 1 minute, should prove after release of the load, the return to the original deflection to within 1/2 mm.</td></tr>
</table>

TAB

Characteristics of the steels us

ADMINISTRATION	Nature and composition of the steel
FRANCE *(continued)*.	
HOLLAND. *Netherlands Railways*	Composition % of the steel used for springs :
NORWAY. *State Railways*	Composition % of the steel used for springs :
LUXEMBURG. *Luxemburg Railways*	According to S. N. C. B. technical specification A. 4 46.
SWITZERLAND. *C. F. F.* (Carriages and wagons only)	Have no technical specification for the supply of steel. Attach particula attention to the supplier, to the control during manufacture and inspectio according to the requirements or the order. The supplier sends a guarante of the quality of the material supplied.

Holland — Netherlands Railways:

C	Mn	Si	P	S
0.40 to 0.55	0.50 to 0.75	1.50 to 1.80	0.05 max.	0.05 max.

Norway — State Railways:

C	Si	Mn	P	S
0.50 to 0.65	1.60 to 1.80	0.55 to 0.70	0.05 max.	0.05 max.

ke laminated springs. *(Continued).*

<table>
<tr><th>Heat treatment</th><th>Mechanical characteristics or required results of tests</th></tr>
<tr><td></td><td>
2° Bend test :
The blade is loaded progressively until, in the reverse deflection, the total deflection is 3/2 of the deflection as made. Should neither crack nor break.
b) Shock test on test piece 200 mm long on the full section of the plate : distance between supports 100 mm — trip of 50 kg — height of drop $\frac{S}{4}$ cm (S = section in mm^2).
The test piece to stand at least 6 blows without crack or break.
</td></tr>
<tr><td>›t given.</td><td>
Mechanical characteristics required :
<table>
<tr><th></th><th>R kg/mm^2</th><th>E kg/mm^2</th><th>A %</th></tr>
<tr><td>Before hardening . . . .</td><td>85</td><td>—</td><td>15</td></tr>
<tr><td>After hardening . . . .</td><td>140</td><td>120</td><td>6</td></tr>
</table>
</td></tr>
<tr><td>ench in water at 20/40° C. Details of heat treatment not given.</td><td>
Mechanical characteristics required :
<table>
<tr><th></th><th>R kg/mm^2</th><th>E kg/mm^2</th><th>A % (1 = 10d)</th></tr>
<tr><td>Before hardening . . . .</td><td>85</td><td>—</td><td>12</td></tr>
<tr><td>After hardening and tem-ring . . . .</td><td>$\geqslant$ 140</td><td>$\geqslant$ 110</td><td>5</td></tr>
</table>
</td></tr>
<tr><td></td><td></td></tr>
<tr><td>ually water hardened. In certain cases oil hardening for for special steels.</td><td>
Mechanical characteristics of the steel used for plate springs of grooved section for light vehicles.
<table>
<tr><th rowspan="2"></th><th rowspan="2">R kg/mm^2</th><th rowspan="2">E kg/mm^2</th><th colspan="2">A %</th><th rowspan="2">△ Brinell</th></tr>
<tr><th>(1=10 d)</th><th>(1=5 d)</th></tr>
<tr><td>After hardening and tempering</td><td>140 to 160</td><td>125 to 135</td><td>6 to 5</td><td>7 to 6</td><td>380 to 420</td></tr>
</table>
</td></tr>
</table>

Norwegian Railways impose a pressure of 50 t and the S. N. C. F. 30 t on the four faces).

b) *Cold buckling.*

Cold buckling has been tested by the S. N. C. F. in the two following ways :

Process A (known as the English method; see figs. 17 and 18).

In this process the buckle has a bottom packing piece A of grooved steel of 37 kg/mm² (23.49 t per sq. in.) with double lugs fitting over the bottom of the buckle. This packing is drilled with a hole in the centre to take the nib of the bottom plate. A flat key B of 48 kg/mm² (30.48 t per sq. in.) steel with a nib is placed in the buckle above the top plate. Between the key B and under side of the top of the buckle a tapered wedge C is driven or pressed in, this wedge having a 2 % taper and being made of 65 kg/mm² (41.27 t per sq. in.) steel. The wedge C is driven with the spring under load with the top plate horizontal. The wedge and key are then welded to the buckle at two places.

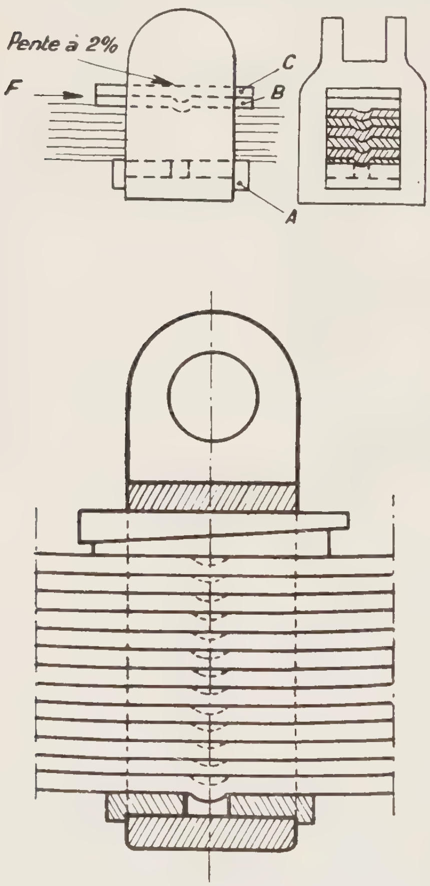


Fig. 17 and 18. — Cold buckling springs packing piece S. N. C. F. Process A. — A. Wedge. — B. Flat plate. — Tightening wedge.

Explanation of French terms : Pente à 2 % = 2 % taper.

A very extensive trial of this system has been made on the *Nord Region* of the S. N. C. F. and the results have been good. The only alterations made as a result of these tests have been to do away with the bottom packing piece and to use a wedge with 4 % taper, which arrangement requires a 15 to 20 t press to put together. It has been decided in future to use the A process on all steam locomotives with buckles without covering (chape).

Process B (figs. 19 and 20) or *Swiss method.*

At the same time as the English method described above, the S. N. C. F. is testing the method used on the C. F. F. electric locomotives for many years (see Part 2).

The required packing piece A is machined to same thickness all over and is then pressed between the top of the buckle and the back plate. The end of an *Allen* type setscrew screwed into the threaded hole in the buckle goes through the hole drilled into this packing piece and holds in position the back plate. The bottom of the buckle is drilled to take the nib of the bottom plate.

The erection is done in two stages : the spring simply held together in a screw press receives the buckle heated to 200° C. The thickness « *e* » of the packing piece A is measured by a gauge and the packing piece machined to it. The piece A is driven in

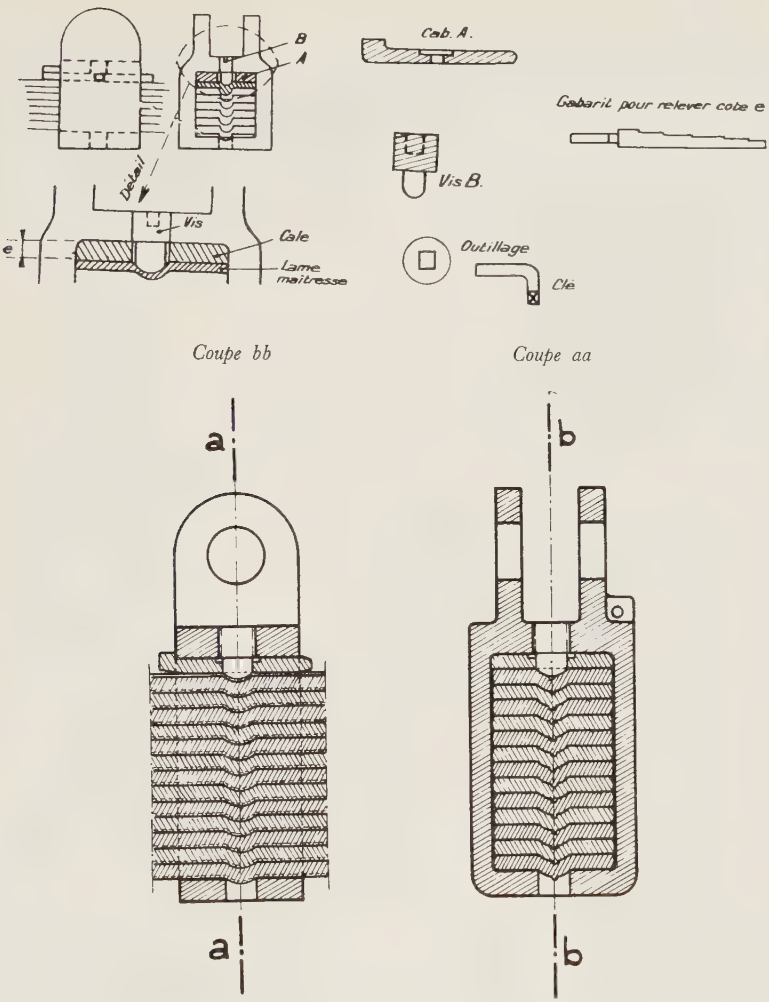


Fig. 19 and 20. — Cold bucking of springs. — A. Packing piece uniform thichness machined as needed. — B. Locking screw. The process has been in use for many years on C. F. F. electric locomotives.

Explanation of the French terms :

Cab. A = Packing piece. — Vis = Set screw. — Cale = Packing piece. — Lame maîtresse = Back plate. — Gabarit pour relever cote e = Gauge to measure e. — Vis B = Set screew. — Outillage = Tool. — Clé = Key. — Coupe aa = Section aa. — Coupe bb = Section bb.

by tup the plate of the spring being held together in the press.

This method is under test on steam locomotives of the S. N. C. F. It has given satisfaction on the C. F. F. electric locomotives (see Part 2).

Question 46. — *What method do you use to prevent the buckle sliding longitudinally along the leaves, one in relation to the other?*

Various arrangements are used :

— by *nibbing* (fig. 21) used by S.N.C.B..

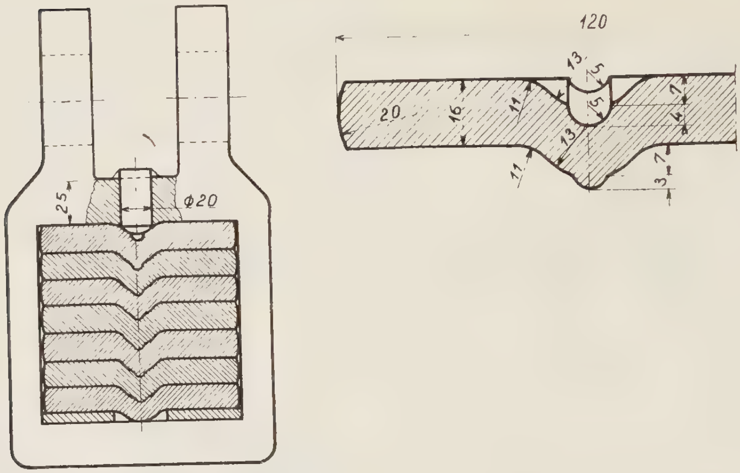


Fig. 21. — Fastening the grooved spring plate by nib (Norwegian State Railways F. 336).

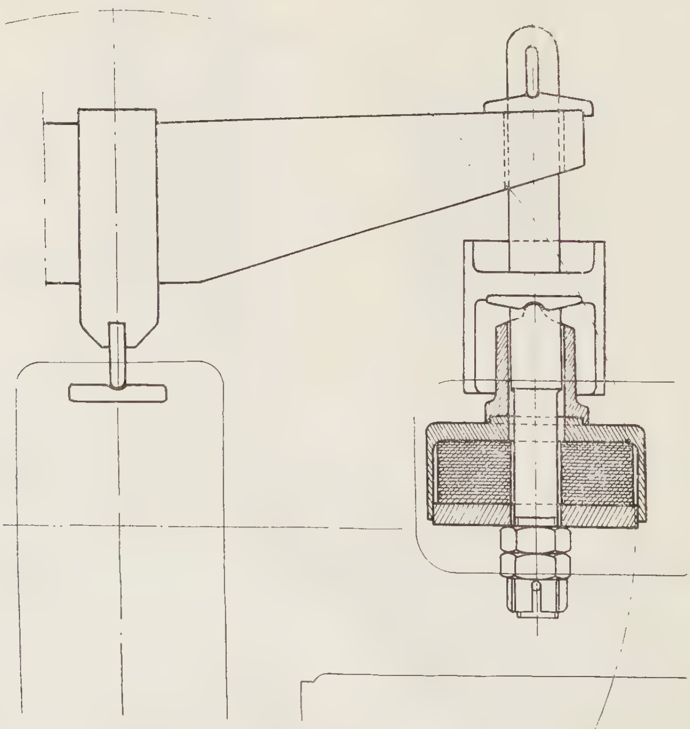


Fig. 22. — India rubber snubbing block fitted to the spring hangers of S. N. C. F. tenders.

Denmark, S. N. C. F., Holland, Luxemburg, Norway and appears to be most widely used;

— by *central rivet* Norwegian, Algerian, Gafsa and formerly, Netherlands Railways, Société Nationale Française des Chemins de fer Economiques and Société Nationale des Chemins de fer Vicinaux belges;

— side pin or key (Denmark).

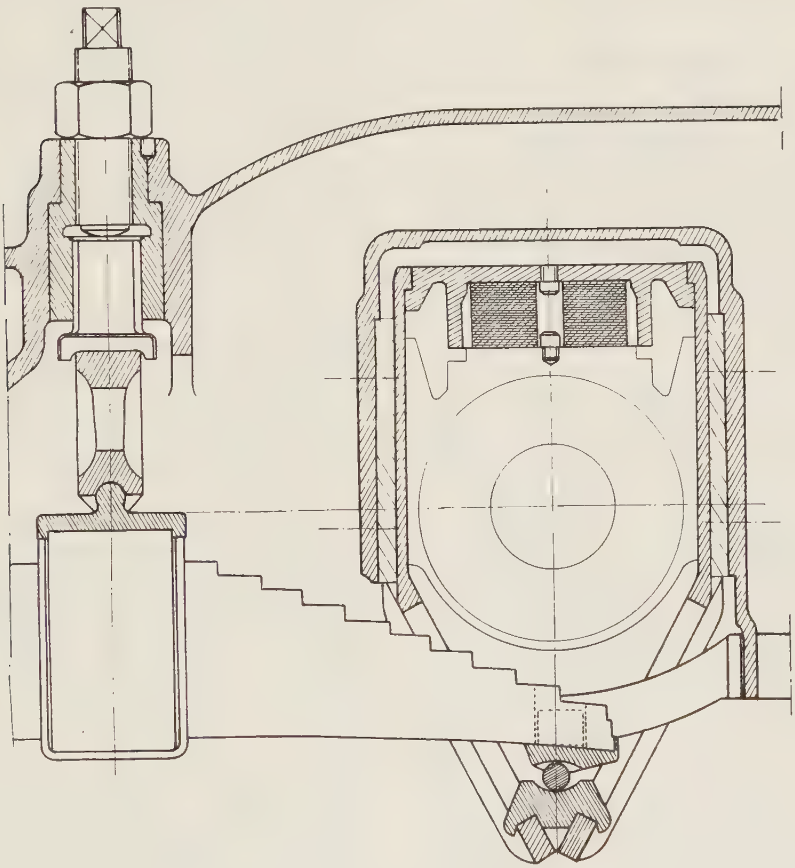


Fig. 23. — Rubber snubbing block fitted on the top of the oil box of tender 34-P of the S. N. C. F.

Question 47. — *Do you use rubber springs (for suspension, for shock and for drawgear, etc)? What are the results obtained?*

There are a number of examples of the use of india rubber in the spring gear of *steam locomotives.* Some of the 4-6-0 locomotives of the Netherlands Railways are fitted with india rubber in place of coiled springs on the spring hanger bolts. After 25 years use it has not been necessary to replace then.

A similar use is on the type 34 P tenders of the S. N. C. F. to snub vibration and shocks. The washers have a central hole and fit over the spring hanger bolts between the adjusting nut and the cup fastened to the frame (fig. 22).

In other instances the rubber snubber is fitted between the top of the box and a cage surrounding it and acting as support for the springs (fig. 23).

The Liberation English locomotives delivered in 1946 to the Luxemburg Railways have rubber buffing springs between the engine and tender.

A series of Danish locomotives have draw gear with rubber springs in place of the usual steel volutes.

The results of these applications are stated to be satisfactory.

***

SECOND PART.

Electric locomotives.

A. — GENERALITIES.

Question 1. — *State the regulations which govern maintenance and periodic repair of locomotives, carriages, wagons, rail cars, etc., What are the conditions of wear of details (e. g. the hollowness of tyre before removal) which have led to the fixing of these regulations?*

The periodical repairs to electric locomotives although alike as between Administrations, vary as regards the periods adopted.

There is always a major operation known as « general overhaul » corresponding to the mileages below :

— 100 000 km for all electric locomotive coaches on the Danish State Railways;

— 160 000, 180 000, 200 000 km for the BB freight, BB mixed traffic and 2D2 passenger S. N. C. F. locomotives;

— 200 000 to 250 000 km for the Ae 4/7 type 2D1 or Re 4/4 type BB. C. F. F. locomotive equivalent to once every 3 years for the Re 4/4;

— 240 000 to 400 000 km for the Norwegian locomotives according to the types and lines;

— 300 000 km for the BB Moroccan locomotives;

— 360 000 km for the Algerian CC locomotives.

During this general overhaul all mechanical and electrical details of the locomotive are restored to good order.

On those Railways on which the mileage between general overhauls exceeds 200 000 km all the locomotives receive, in between repairs of less importance known as heavy lift (150 000 km — Moroccan Railways), heavy repair (120 000 to 200 000 km — Norway) or lift (90 000 km — Algeria). During these operations the tyres are always turned up.

If we consider tyre turning, this is done at the following intervals :

S. N. C. B. — Not enough experience to draw up rules.

Denmark. — 100 000 km.

S. N. C. F. — 160 000 to 200 000 km — for BB freight engines or 2D2 passenger engines respectively.

Algeria. — 90 000 km.

Morocco. — 150 000 km.

Norway. — 120 000 to 200 000 km.

C. F. F. — 200 000 to 250 000 km for the Re 4/4 and Ae 4/7.

The need to turn up tyres decides the periods between repairs given above (the S. N. C. F. and C. F. F. limit the hollow on the treads to 5 mm [13/64″]).

Between the above operations to the tyres, there are inspections of the electrical equipment limited to examination or replacement of units (3 000 to 10 000 km according to the machines on the S.N.C.F.; between 10 and 20 days on the Norwegian Railways).

Question 2. — *Can it be said generally that mileage between repairs has been increased with improved modern rolling stock and locomotives? If possible give examples.*

Observations on increasing mileage between repairs are limited. The results the S. N. C. F. obtained from the BB type 8100 put into service in 1947 enable us to expect favourable results from the mechanical improvements (suppression of play by guiding the boxes by rods instead of

slides). The first unit, by the 15th November 1949, had run 220 000 km exceeding by 40 % the mileage of older machines and the tyre wear then was not enough to shop the locomotive.

The Norwegian Railways have with their recent machines increased the mileage to 200 000 km as compared with 120 000 km on the previous machines.

The BB machine 251 of the Bern-Loetschberg-Simplon has run 485 000 km before reprofiling the tyres. This Railway considers the improvements made to this class has reduced the repair costs considerably as compared with those of the Ae 6/8 class.

In question 21 is given an example of the value of connecting the bogie quoted by the C. F. F.

Question 3. — *When ordering new rolling stock and locomotives, is consideration given to maintenance costs in the specification, and if when ordering modern stock are endeavours made to reduce these costs? Indicate if the Railway administration endeavours to obtain similar results by the modification of stock in service.*

The electric locomotives have been ordered to extend the electrified system or to increase the speed but in the new orders methods for reducing repair costs will be introduced.

B. — ONE PIECE WHEELS.

Question 4. — *Have you had experience with solid wheels?*

No application of one piece wheels to electric locomotives has been reported, they are to be found on electric rail motor coaches.

Questions 5 to 14. — Without application to electric locomotives in view of the replies to Question 4.

C. — TYRED WHEELS.

Question 15. — *What quality of metal of tyres (chemical analysis and physical characteristics, method of manufacture and especially type of heat treatment)?*

The tyres on electric locomotives are of the same steel as those on steam locomotives (1st Part — Question 15).

Tests are in hand on the S. N. C. F. of tyres of harder steel than the A75 usually used.

Table 13 sums up these tests and gives the results obtained to the 1st December, 1949, by the above named Administration.

Tests with hard tyres are in hand with BNAV2 steel on the driving and carrying axles of 8 — 2D2 locomotives and with an improved 90 kg/mm² carbon steel on the carrying axles of 46 locomotives.

Tests on the C. F. F. with heat treated carbon steel to give 110 kg/mm² were not satisfactory especially under long braking owing to fine cracks on the tread and cracks in the flanges.

Question 16. — *What are the measures that you have adopted to reduce to a minimum the risk of loose tyres? (State of surface after machining, diameters of the wheel centres and tyres in contact before mounting, system of heating tyres, etc.). Do you weld at the rim to prevent loose tyres?*

The regulations are the same for electric and steam locomotives (see 1st Part). On the C. F. F., the carriages alone are braked on long down grades mechanically, the electric locomotives being braked electrically.

Question 17. — *What are your specifications regarding the minimum thickness of tyres according to the load or maximum speed permitted for vehicles (minima both after repair and in service)?*

Table 14 gives the minimum thickness at the tread on leaving shops after last turning and at the limit of wear before withdrawal from service and replacement.

TABLE 13.

Comparative tests of tyres in ordinary steel and special steel on the S.N.C.F. 2D2 Electric locomotives.

Class of steel	Type of axles fitted	Number of tyres under test	Number of times re-turned	Average mileage between turning up
S. T. 14 steel 75-86 kg/mm^2	Driving axles	53	90	262 300
— ditto —	Carrying axles	28	59	164 500
BEDEL BNAV2-Ni-Cr-Mn steel heat treated at 110/120 kg/mm^2	Carrying axle	1	1	434 800
		1	1	372 800

Question 18. — *When wheels have flats do you repair by building up by welding and making good the tyre surface by grinding or turning?*

The same as for steam locomotives (see 1st Part).

Question 19. — *In addition to choice of metal and its treatment do you employ other methods to reduce tyre wear (e. g. lubricating flanges or rails)?*

In the first part the preference in the case of steam locomotives is towards lubricating the rail. Certain Railways however still prefer to lubricate the flanges. This is so on the C. F. F. where flange lubricators are largely used, whether the simple pad applied by a spring on the « Charmilles » system which gives entire satisfaction. Certain mileages between repairs have been trebled (Ee 3/3 locomotives increased from 16 000 to 50 000 km) and the rail motor coaches of the Brunig on which the flange lubricators alone increased the mileage from 6 000 to 20 000 km.

Some of the Moroccan Electric Locomotives have hard carbon blocks which rub against the flange. These blocks before fitting are soaked in hot oil.

Question 20. — *Have you found with locomotives that the lateral displacement of the axles influences tyre wear?*

Question 21. — *Have you proved that lessening of hunting (particularly lessening the rotation of the bogie round its pivot) reduces tyre wear?*

The C. F. F. shows that the wear of flanges is reduced by coupling the two bogies of a BB locomotive transversely between themselves and calls attention to the value of a spring articulation with initial tension (fig. 24). Such a coupling conjugates the oscillation of the bogies and diminishes the angles of attack of the guiding wheels. These transverse couplings are most effective. On the Brunig line, which has very many curves, the rail motor coach mileage has risen from 20 000 to 100 000 km.

Question 22. — *Have you tried or do you use independent wheels? What has been your experience with these wheels regarding tyre wear?*

No such test has been reported.

TABLE 14.

Minimum thickness of tyres on electric locomotives.

ADMINISTRATION	Types of locomotives and axles or nature of service worked	Minimum tyre thickness	
		Out of shop after last turning (in mm)	Limit of wear in service before withdrawal (in mm)
BELGIUM *S. N. C. B.*	All electric locomotives	35	30
FRANCE *S. N. C. F.*	Driving axles of 2D2 or BB electric locomotives with heavy axle loads Braked carrying axles of 2D2 locom.	50	45
	Driving axles of the other classes of electric locomotives Unbraked carrying axles of the 2D2 electric locomotives	45	40
Moroccan Railways	All electric locomotives	—	40
NETHERLANDS *Netherlands Railways*	Driving axles according to the type of locomotive	40 to 55	The thicknesses are not checked in service
	Carrying axles: braked	35	
	Carrying axles: unbraked	30	
NORWAY *State Railways*	All train electric locomotives	40	—
SWITZERLAND *C. F. F.*	All train locomotives :		
	Driving axles	40	35
	Carrying axles	35	30
	Other locomotives	35	30
Emmenthal - Burgdorf - Thun Railways (Switzerland)	Electric locomotives	—	40

D. — AXLE BOXES.

a) Roller bearing boxes.

Question 23. — *Do you use roller bearings? If so kindly say what results have been obtained regarding :*
1) *Number of hot boxes;*
2) *Maintenance costs;*
3) *State period between lubrication and inspection.*

application carried out. The S. N. C. F. so far has applied roller bearing boxes only to carrying bogies. One of the thirty-five 2D2 locomotives ordered for the *Paris-Lyon* electrification will have as a test roller bearing boxes an all axles.

These applications are expected to reduce *maintenance costs.* Over-heating is extremely rare. The S. N. C. F. report trouble with *Timken* boxes with oil lubrication due

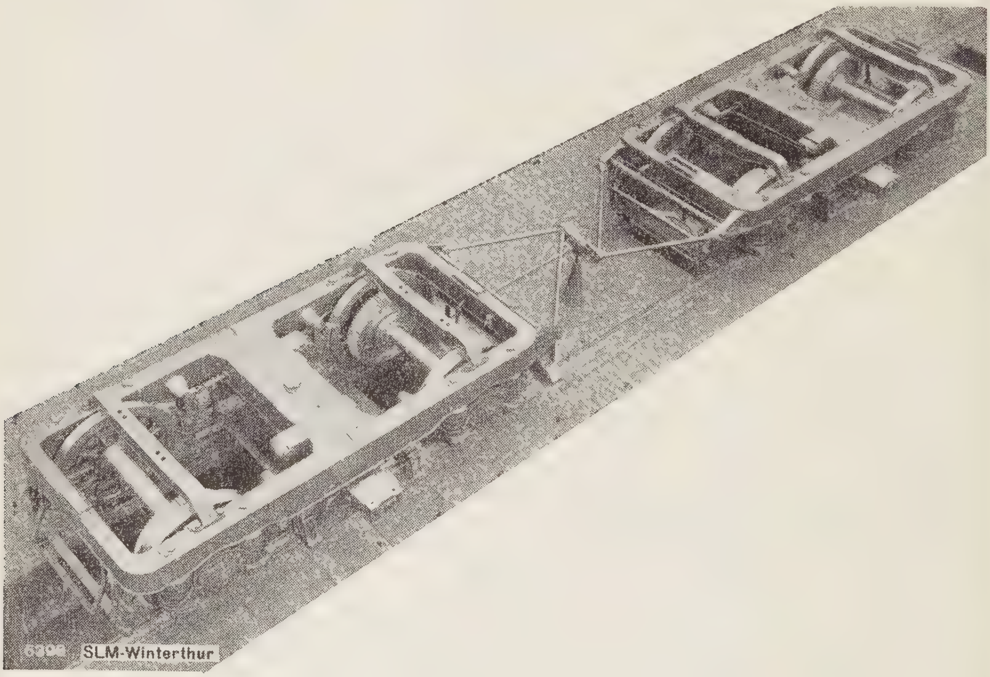


Fig. 24. — Spring transverse coupling between bogies on C. F. F. electric locomotives.

Question 24. — *Have you found any difficulties due to the use of axle boxes of this type? Please indicate (fractures and wear of details, damage through rough shunting, etc.).*

Three Railways use roller bearing boxes on electric locomotives, the S. N. C. B., S. N. C. F., and C. F. F., which have particularly tested this type of box on driving axles.

The reply to question 25 gives the to erosion or distortion of the bodies of the boxes (see Question 29) : the C. F. F. have not recorded any defects.

The S. N. C. F. take down, clean and refill with grease the box at general overhaul, i.e.: after 180 000 km. Every 360 000 km the races are to be removed for the axle to be inspected. On the C.F.F. the boxes are regreased every 3 to 4 years.

As regards savings, the balance sheet with

roller bearing axle boxes on electric locomotives cannot be drawn up from the replies. On the S. N. C. F., the electric locomotives with roller bearing boxes are compared with those fitted with boxes of the *Athermos* type with continually circulating oil, which have been satisfactory. The boxes used on the C. F. F. are S. K. F. on all main line locomotives built since 1946.

Question 25. — *What type of roller bearing box to you use (cylindrical, conical or roller bearings)?*

Table 15 gives particulars of the principal applications of roller bearings on electric locomotives.

Question 26. — *What type of protection do you use against the penetration of dust and water into the interior of the box?*

The answer is the same as for steam locomotives (1st Part — Question 26).

Question 27. — *What are the loads per axle and the speeds permitted for the boxes you use? Give principal dimensions, catalogue number, drawing, etc.?*

Table 16 gives the requested information.

Question 28. — *What is the system of mounting the rollers on the journal? What are the advantages and disadvantages of the system used?*

The reply is the same as for steam locomotive (1st Part).

Question 29. — *Do you use special arrangements to prevent electric current passing through the roller bearings (current for traction or heating)?*

The S. N. C. B. report they are not using such devices on their BB locomotives.

The S. N. C. F. report that such devices have never been used on its 2D2 electric locomotives, of which the carrying wheels alone are fitted with roller bearing boxes.

This arrangement has always been satisfactory with S. K. F. boxes using S. K. F. 28 grease.

On the other hand, the rollers and sparers of the oil lubricated *Timken* boxes have shown erosion and pitting ascribed without it being possible to confirm it as due to the passing of the current. This has not occurred on the few boxes lubricated with S. K. F. 28 grease. The S. N. C. F. is following this experiment.

In the case of a 2D2 locomotive under construction with all axles (driving and carrying) fitted with S. K. F. roller bearing axleboxes, the S. N. C. F. is designing a special device for the return of the current.

The C. F. F. uses fittings to prevent current passing not only through the roller bearings on the driving axles of their electric locomotives but also through the ordinary bearings on other locomotives owing to the use of roller bearings in the BBC drive. The fitting is usually a brush rubbing on a disc fastened to the wheel centre.

b) Axle boxes with plain bearings other than the ordinary boxes with lubricator pads or packings.

Question 30. — *Describe what types of axle boxes having bearings or brasses other than ordinary axle boxes do you use?*

Question 31. — *What is used for the lubrication of these axle boxes (grease or oil)?*

The *Athermos* continuous oil circulating box is used widely on the S. N. C. F. goods and mixed traffic BB, and passenger 2D2, CC, BBB locomotives, on the Norwegian (*Peyinghaus* box) and on the Moroccan Railways.

These boxes were described in connection with steam locomotives (see 1st Part).

The Netherlands Railways use on the 1000 class machines *Bop-Assa* boxes lubricated by central oil pumps.

TABLE 15.

Applications of roller bearings to electric locomotives.

ADMINISTRATION	Types of boxes fitted	Types of locomotives and axles fitted	Max. speed	Mileage without defects	Remarks
BELGIUM *S.N.C.B.*	Double row SKF outside boxes	26 loc. BB (at 20.5 t per axle)	100 and 125	—	Now being supplied
FRANCE *S. N. C. F.*	Double row SKF outside boxes with double row of rollers grease lubricated (diag. fig. 1).	1 loc. 2D2 (carrying axles) 11.5 t load	100	1 700 000	The application to 25 engines of this class has been arranged.
	Double row SKF inside boxes with double row of rollers, grease lubricated.	1 loc 2D2 (carrying axles) 14 t load	130	950 000	
	Single row *Timken* inside boxes with two rows of tapered rollers (diag. fig. 4) oil lubricated.	5 loc 2D2 (carrying axles) 14 t load	100	Not yet checked	Heating due to cages breaking or erosion of the rollers.
	Timken inside boxes lubricated with stiff grease.	1 loc. 2D2 (carrying axles) 14 t load	100	d°	Grease lubrication gives very good results with these boxes.
SWITZERLAND *C.F.F. and others*	Double row SKF boxes	C. F. F. Re 4/4, Ae 4/7, Ae 4/6, BLS, Ae 4/4 and Ae 6/8 type locomotives	125	—	Satisfactory tests over 4 or 5 years. No heating since 1946.

Characteristics of SKF bearings fitted on electric locomotives (classed by diameter of journal in ascending order.)

Catalogue number of the bearing	Number of bearings per box	Projected length of the bore of the bearing in mm	Exterior diameter of the bearing in mm	Min. diameter (1) of the bore of the bearing sleeve	Diameter of the journal in mm	Wheel diameter in mm	Maximum speed of the locomotive in km/h	Maximum axle load in t	Locomotives fitted: Administration	Locomotives fitted: Type and class	Locomotives fitted: Number
22 328 K with tapered sleeves	2	102	300	140	130	900	100	11.5	FRANCE *S. N. C. F.*	2D2 5000 (bogies)	1
22330	1	108	320	150	140	1040	125	14	SWITZERLAND *C. F. F.*	BB (Re 4/4)	50 (delivery not completed)
I 37 606	2	102	300	160	150	1350	100	20.6	BELGIUM *S. N. C. B.*	BB 101	26 locomotives being supplied
— d° —	2	102	300	160	150	1260	125	20.2	— d° —	BB 120	
22-338 K	2	132	400	190	180	1350	125	20.2	— d° —	BB 121	
— d° —	1	132	400	190	180	1250	125	20	SWITZERLAND *B. L. S.*	BB (Ae 4/4)	4
23 136 fitted hot	2	96	300	180	180	970	130	14	FRANCE *S. N. C. F.*	2D2 5500 (bogies)	1
— d° —	2	96	300	180	180	970	140	16	— d° —	2D2 9100 (bogies)	35 under construct.
23 248 fitted hot	2	160	440	240	240	1750	140	23	— d° —	2D2 9100 (driving axes)	1 under construct.
Characteristics of TIMKEN tapered bearings used on electric locomotives.											
280709/281200 fitted hot	1 double	69	305	180	180	970	100	14	*S. N. C. F.*	2D2 5500 (bogies)	5 (oil lubricated) 1 (grease lubricated SKF 28)

(1) When the bore is tapered.

Question 32. — *What type of protection is used against the penetration of dust and water to the interior of these axle boxes?*

See reply for steam locomotives (1st Part).

c) Improvements in ordinary axle boxes with bearings and brasses.

Question 33. — *What improvements have you carried out to brasses and oil pads?*

No recent improvement is reported in connection with the brasses and lubricators of electric locomotives. The C. F. F. use boxes with lubricator pads with a revolving disc to pick up the oil.

Question 34. — *What type of anti-friction alloy is used? Is there a preference for the use of anti-friction metal rich in tin, according to the type of vehicle (load and speed)?*

Question 35. — *Describe the method of applying the anti-friction metal (grinding, centrifugal, sintering, fritting, etc.) and the minimum thickness of the layer.*

The information given is the same as that given for steam locomotives in the 1st Part. The Netherlands Railways point out that the thickness of white metal is only 6 mm against 8 mm on the electric locomotives or 10 mm for their steam locomotives. The C. F. F. find that alloys with less than 80 % tin have not been satisfactory.

d) Present tendencies in the choice of the type of axle box.

Question 36. — *Set out the different categories of locomotives and rolling stock, and the various types of service which govern the choice of the type of boxes to be adopted, showing the reasons.*

Some Administrations have indicated their present preferences for use on new construction. These tendencies are summed up below with the reasons justifying the selection.

S. N. C. F. (France).

For modern stock or projected the S. N. C. F. (*France*) is using at present two designs :

— the roller bearing axle box (S. K. F. or *Timken*);

— the *Athermos* axle box.

The *Athermos* box is used in most cases. The application of S. K. F. or *Timken* roller bearing boxes is recent and their use applies to only part of the stock.

So far roller bearings have only been used on the carrying axles of high speed locomotives and rail motor coaches.

Their use on locomotive driving axles is bound up with the satisfactory development of a return current device.

S. N. C. B. (Belgium).

The new BB electric locomotives which will be put into service in the near future are all with roller bearing boxes, and experience obtained with the electric rail motor coaches fitted with such boxes permits their use to be considered on future electric locomotives.

Netherlands Railways (Holland).

The latest BB electric locomotives supplied have ordinary plain bearing boxes to get the quickest possible delivery, but the future locomotives are to have roller bearing outside bixes.

Moroccan Railways.

The new electric locomotives will have *Athermos* boxes with plain bearings and mechanical lubrication as the results obtained are satisfactory and the price is lower.

Norwegian Railways.

A batch of electric locomotives with individual axle drive under construction will have roller bearing boxes.

Swiss Federal Railways and B. L. S.

The use of self-aligning roller bearing boxes is usually provided on any main line locomotives to be built.

The C. F. F. report that their higher first cost by 40 to 50 % is more than balanced by : the suppression of overheating, the lower cost of repairs, the absence of exa-

mination in service and the reduction in rolling friction.

E. — WEARING AND FRICTION METALS.

Question 37. — *What are the details, in your opinion, the wear of which limits the mileage between repairs?*

Generally, apart from the tyres the parts limiting the mileage between repairs by their wear are :

Pin joints in the spring and brake gear (pins and bushes);

Axlebox guides;

Traction motor armature bearings and axle bearings of nose suspended motors.

Question 38. — *What materials are used to reduce the wear of details subjected to friction (axle box guides, various joints, etc.).*

Axlebox guides.

To reduce wear due to friction the S. N. C. F. uses manganese steel. In certain cases where the required accuracy of machining will not allow manganese steel to be used, nitrided steel is used (for example the centre pin of the equaliser lever of the bogie pivot of the 2D2 9100 locomotives under construction). Nitrided steel is also under consideration for axlebox guides.

Table 17 summarises the tests on the S. N. C. B. and S. N. C. F.

TABLE 17.

L[illegible] on electric locomotive boxes and guides.

		Liners on guides fastened to the frame	Liners fitted to the boxes	Remarks
S. N. C. F.	Normal arrangement	Manganese steel	Manganese steel	
	Tests on driving axles of 2D2 locomotives	Nitrided steel	Manganese steel	To be carried out on 5-2D2 locomotives on the Paris-Lyon line.
	Trial on driving axles of 2D2 locomotives	B 3 bronze	Manganese steel	30 - 2D2 locomotives under construction.
	Trial carrying axles of 2D2 locomotives	B 3 bronze	Case hardened and quenched steel built up on the flanges with Valchrite Co-Mo-Mn self-tempering steel.	Bogies of the 2D2 locomotives under construction.
S. N. C. B.	BB locomotives driving axles	Castiron : R = 40 kg/mm²	Bronze with 11 % Sn and 0.3 % Ph.	
C. F. F.	All axles	Castiron or bronze	Cast- or case hardened steel	Use of Mn steel under consideration.

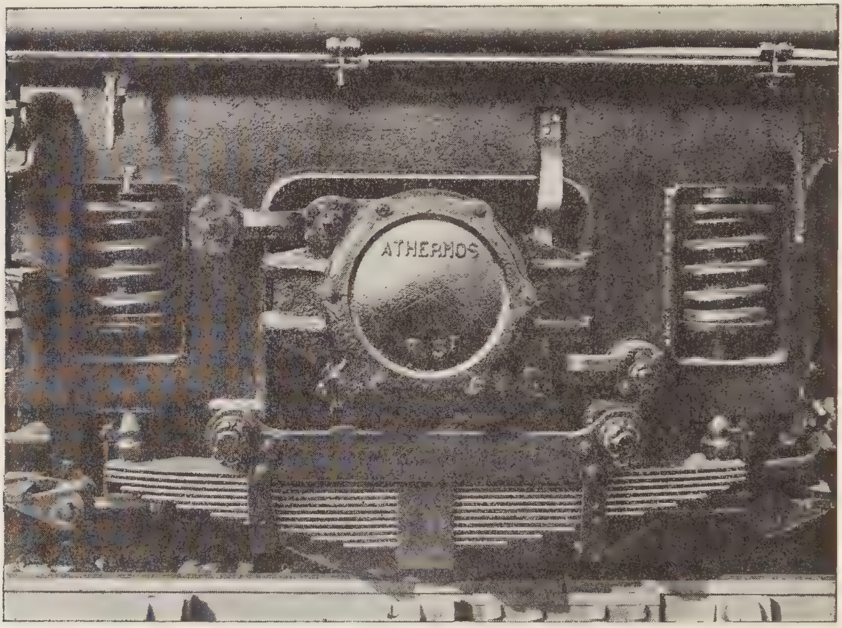
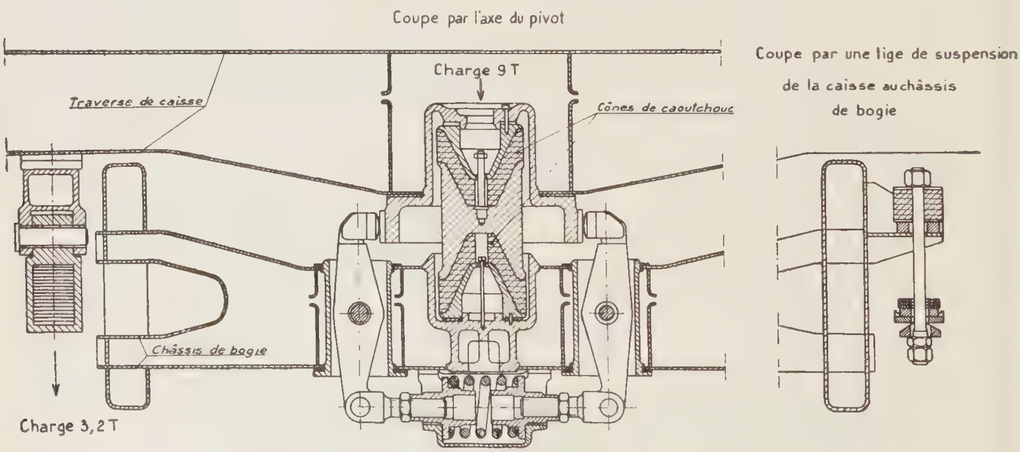


Fig. 25. — Linkage of axle boxes to bogie frame by rods and silent blocks on BB 8101 electric locomotives of the S. N. C. F.



Recoil { initial : 500 kg
final : 4 500 kg for 34 mm

Fig. 26. — Pivot with inverted rubber cones on the bogies of BB Alsthom 8001 electric locomotives of the S. N. C. F.

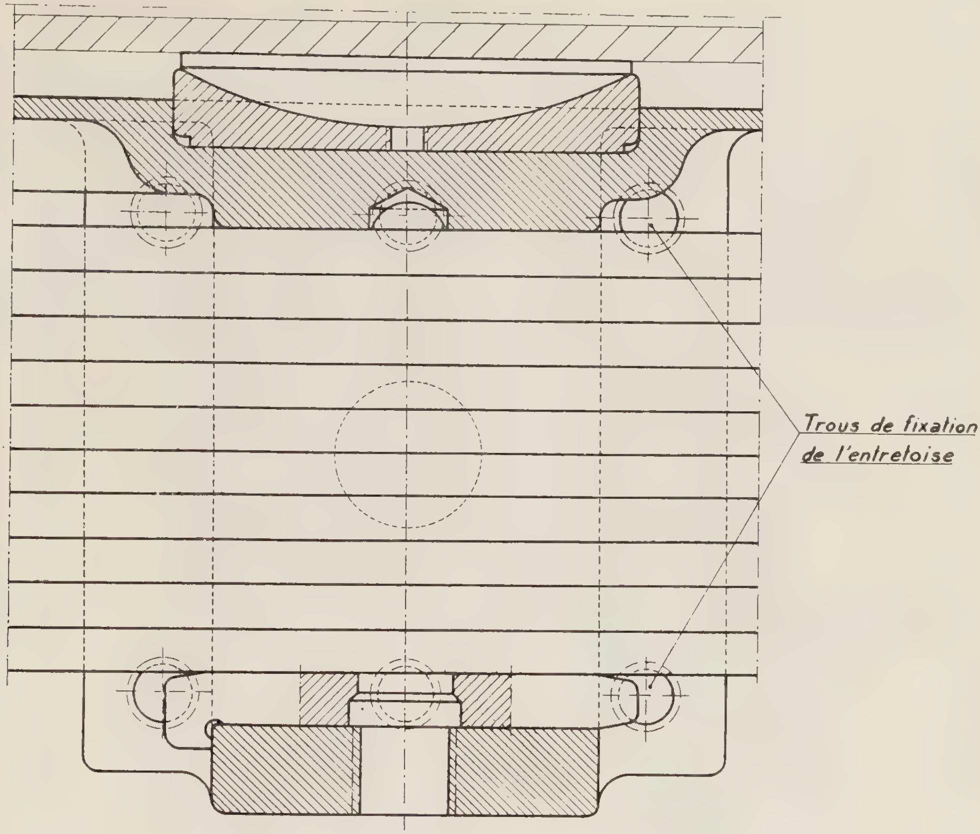


Fig. 27. — Cold buckling of springs used by the C.F.F. on electric locomotives.

Question 39. — *What methods have you adopted to make good worn details (e. g. fitting washers or bushes at joints, using easily replaceable wearing portions, etc.)?*

Same reply as for the steam locomotives (1st Part. Question 39).

Question 40. — *Have you adopted any special arrangements to avoid reciprocal friction between the different details (e. g. guiding by articulated links on silent block, etc.)?*

A new technical approach is to be seen on modern stock to the suppression of all play and rubbing of metal parts together by taking advantage of the elastic properties of india rubber.

The *axle boxes* of the BB 8001, and CC 7001 locomotives of the S. N. C. F. are linked to the frame by two articulated rods with silent-block bushes at each end (fig. 25).

The axlebox has two lugs arranged symmetrically at the two ends of a diagonal centre line. The great torsional elasticity of the silent blocks allows the axle to move vertically up and down from the static mid-position of the springs whilst always remaining on the same vertical line. On the other hand, the radial elasticity of the silent-block bushes is very small and practically does not adversely interfere with the vertical plane of the axles remaining fixed.

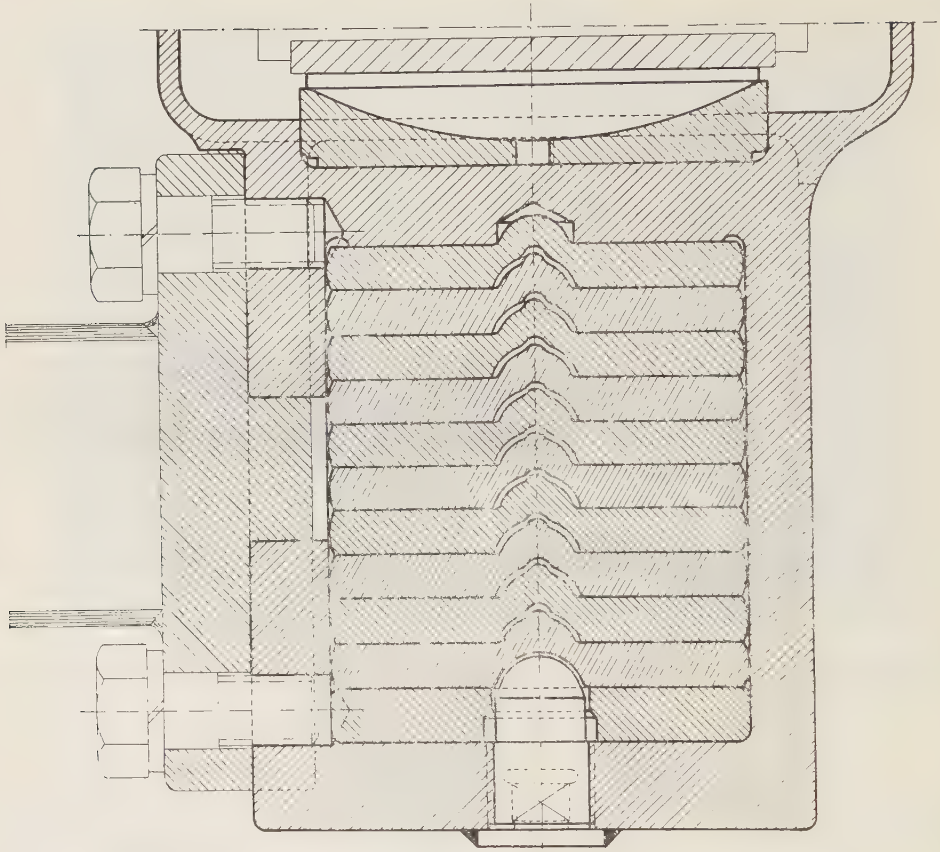


Fig 27. *(continued)*.

By conical deformation, the silent-block bushes allow some transverse play of the axles under a self-centring force this arrangement does away with the slides and thereby with their attendant worries of lubrication, wear, and renewal.

A similar use of rods with silent-block bushes attached to the motor casing and at the other end of the bogie frame has made it possible to *suppress the side shoulders* of the motor axle bearing brasses, always difficult to lubricate and usually subjected to severe shocks. This method has been used on the S. N. C. F. BB 8100 locomotives.

The pivots on the BB 8001 are fitted with rubber cones which give vertical elasticity. These cones allow rotation, rolling, and transverse movement between the bogies and the body by simple deformation of the elastic material without any surface rubbing, thereby suppressing all wear and all lubrication (fig. 26).

The Netherlands Railways will use the same guiding arrangement by rods on their Bo-Bo electric locomotives being built.

On the C. F. F., recent stock (loc. Re 4/4, Ae 4/4) the boxes are guided by cylindrical case hardened tempered and ground plungers. On each part slides a bronze bush

secured to the axlebox body by a silent block fitting (see fig. 28). The bush slides in an oil bath.

The S. N. C. F. call attention to a great improvement as regards repairs by fitting grease lubricated roller bearings to the *traction motor armature shafts.* These bearings should require lubrication only at general overhaul. Unlike the armature bearings the axle casing bearings of nose suspended motors of the BB locomotives continue to be plain bearings lubricated by oil.

a) *For laminated springs;*
b) *For spiral springs;*
c) *For volute springs.*
d) *For other types of springs (torsion bar, etc.).*

Question 43. — *Are these failures brought about by the quality of steel, the design of spring, or manufacturing processes (state especially if you use oil or water hardening steels and the results obtained in each case; state quality of the steel used)? In those cases where the quality of steel is the cause, what arrangements have you adopted to ensure the consistent quality of steel? Attach specifications and state what steps you take to ensure the correct quality of steel being supplied.*

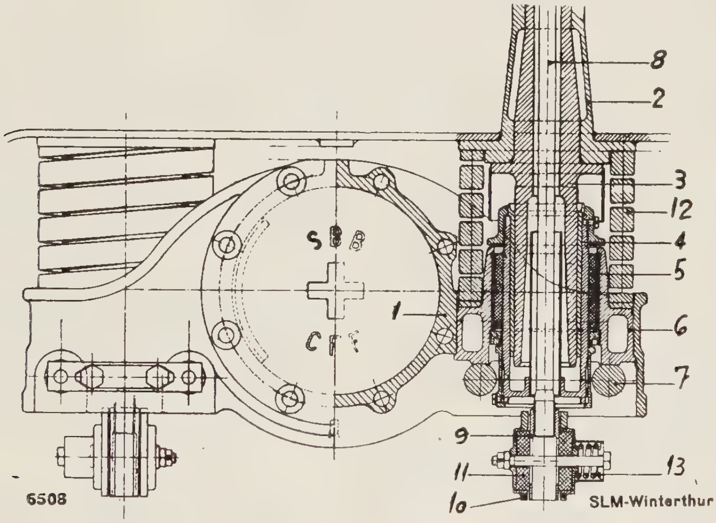


Fig. 28. — Helical spring suspension with shock absorber on recent electric locomotives of the C. F. F.

Question 41. — *Do you use with spring suspension details any protection devices on the parts subjected to friction (supports for the adjusting spring links, buckles, etc.)?*

An application of wearing liners is reported by the S. N. C. F. These are thin Manganese steel plates welded to certain equaliser beams and details acting as guides.

F. — SPRINGS.

Question 42. — *What methods have you adopted to lessen the number of spring failures (weakening, fractures, etc.)?*

Question 44. — *Do you use special mounting arrangements in order to prevent movement not provided for (guiding, joints in the case of spiral springs, etc.)?*

Question 45. — *Are laminated springs buckles fitted hot or cold? State methods, process and results obtained?*

Question 46. — *What method do you use to prevent the buckle sliding longitudinally along the leaves, one in relation to the other?*

For the replies to Questions 42 to 46 above, please see those for steam locomotives (1st Part — Questions 42 to 46).

The value of cold buckling for electric locomotives is stressed by the C. F. F. The method adopted has been described under Process B for steam locomotives and is shown in figure 27.

In the fifth Part dealing with coaches, the value which the C. F. F. attributes to coiled springs of *square section* is pointed out. Figure 28 is an example of the use of such springs (item 11) combined with friction dampers used on the recent C. F. F. electric locomotives.

Question 47. — *Do you use rubber springs (for suspension, for shock and for drawgear, etc)? What are the results obtained?*

Information has been received from the S. N. C. F. whose recent locomotives show a marked tendency towards the wider use of rubber for damping, by inserting blocks of suitable form either at the ends of the plate springs (locomotive CC 7001/2) or to the ends of the suspension brackets (locomotives BB 8001) or for fastening the motors (locomotive BBB 6002) or sets or equipment (wagon-sub-stations).

There is however insufficient experience of all rubber suspension springing whether for the main or secondary springing to form any conclusion.

The use of *Spencer Moulton* type buffer springs with the rubbers piled together with steel dividing plates between each (7 springs per buffer) is general on new electric locomotives.

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THIRD PART.

Railcars with internal combustion motors.

A. — GENERAL.

Question 1. — *State the regulations which govern maintenance and periodic repair of locomotives, carriages, wagons, rail cars, etc., What are the conditions of wear of details (e. g. the hollowness of tyre before removal) which have led to the fixing of these regulations?*

Question 2. — *Can it be said generally that mileage between repairs has been increased with improved modern rolling stock and locomotives? If possible give examples.*

The tyres are turned up after mileages of 60 000 to 100 000 km:

60 000 km — Algerian Railways;

80 000 km — S.N.C.B. (Repairs A or B);

90 000 km — S. N. C. F. (Luxemburg and Norway);

100 000 km — Denmark.

As regards the overhauls of motors and body, the figures vary widely according to the type of motor and the Railway. As the object of this report is to examine improvements in the running gear and frame, information as to the overhaul of motors and bodies is not given.

The S. N. C. F. state that the tyres determine the mileages given above. The Netherlands Railways report that repairs are mainly due to two causes: abnormal play and tyre wear and that in new stock with roller bearings and manganese steel guides the wear of tyres is the determining factor.

B. — ONE PIECE WHEELS

Question 4. — *Have you had experience with solid wheels?*

Table 18 gives the application of one piece wheels to railcars.

Question 5. — *If so, what are the results which you have obtained or hope to obtain by using solid wheels from the point of view of regularity of the service? What are the advantages and disadvantages already established?*

The one piece wheel has been adopted to prevent tyre movement and to reduce weight (lightening is more important on railcars than on other stock). The S.N.C.F.

TABLE 18.

Application of one piece wheels to railcars.

ADMINISTRATION	Railcars with one piece wheels	Date put into service	Diameter of wheels in mm	Maxim. speed in km/h	Rim thickness in mm	Kind of steel and remarks
BELGIUM *S. N. C. B.*	1 railcar fitted experimentally with : 1 bogie with wheels of special steel 1 bogie with wheels of ordinary steel.	1947		120		Chrome-Molybdenum steel Carbon steel
FRANCE *S. N. C. F.*	About 500 railcars of various types		860	120 to 140	25	Cr-Mo forged steel
	Some fifteen light railcars will 4 independent axles		860	90		Delachaux « Infatigable » cast steel
Société Générale des Ch. de fer Economiques (Brittany System)	Metre gauge railcars	—	430 (about)	70		Cr-Mo forged steel
Gafsa Railways	Some railcars supplied with one piece wheels	—	—	—	—	Cr-Mo steel (these wheels were removed after running average of 60 000 km)
Indo-Chinese Railways	A number of railcars	—	—	—	—	G carbon steel
NETHERLANDS *Netherlands Railways*	Diesel-electric rakes	1934	900	125	45	Carbon steel. The one piece wheels have been replaced by tyred wheels.

report that a tyred wheel weighs 100 to 125 kg per metre diameter more than the one piece wheel.

The behaviour in service of one piece wheels on railcars was very satisfactory before the War. At the present time it is less so through the quality of the metal being poorer. The most usual defect is cracking starting in the disc of the wheel often at the driving holes and ending in fracture. The experience up to date is insufficient to state if there is more or less flaking or shelling with one piece wheels than with tyred wheels.

The Netherlands Railways as on their electric rail motor coaches have found cracks in the wheels on Uerdingen hollow axles, especially in the case of braking on discs or drums which raises the question of the dispersion of heat through the body of the wheel itself.

The « Société Générale des Chemins de fer Economiques » (France) report that chrome-molybdenum steel one piece wheels have run 180 000 km without any defect to report. The Gafsa Railways has not got more than 60 000 km with the same chrome-molybdenum steel.

The results obtained are therefore very variable and appear to depend upon the conditions of use and on the quality of the metal. An improvement in the quality of the metal is needed to get back to the satisfactory results the S. N. C. F. got before 1940.

Question 6. — *The same question from the cost point of view.*

No balance sheet has been supplied. The S. N. C. F. report that the chrome-molybdenum steel wheel which originally cost twice the price of the tyred wheel, now cost one and a half times as the design has been simplified. Although no balance sheet has been drawn up this Railway thinks the one piece wheel of value because of its lighter weight mentioned above.

Question 7. — *Do you use solid wheels on vehicles running at high speeds?*

The speeds run with one piece wheels are given in Table 18 hereafter.

Question 8. — *Do you use them on braked vehicles (braking on running surface, on brake drum, or on the wheel centres)? What material is used for brake shoes? What advantages and disadvantages have been established?*

The railcars are generally fitted with brake blocks. Braking on drums or discs is mentioned by the S. N. C. F. and the Netherlands Railways (we have mentioned under Question 5 the cracks found in some axles braked on drums fastened to the wheel centres).

Question 9. — *What metal is used for solid wheels (chemical analysis and physical characteristics)?*

Question 10. — *Do you use special methods of manufacture in order to obtain the appropriate characteristics of the metal in the different parts of the wheel?*

In addition to the 70 kg/mm² ordinary carbon steel chrome-molybdenum steel is used (the S. N. C. F. uses a steel with C = 0.45 %, Chrome = 1.15 to 1.25, Mo = 0.45 to 0.55, hardness 110 kg/mm²).

No method of surface hardening has been reported.

Question 11. — *Can the solid wheels which you use be re-profiled, by the depositing of metal, by turning, etc., and what are the thickness limits in each case*

Question 12. — *In the case of wheels having flats do you repair on site by building up by welding and making good the tyre surface by grinding or turning?*

Question 13. — *After several returnings are you able to retyre wheels which originally were solid wheels?*

The S. N. C. F. which use Cr-Mo steel

wheels 25 mm thick at the rim turn up these wheels and grind them without adding metal until a limit thickness of 7 mm measured on the outer edge. Tyring these wheels has not been provided for.

The Indochina Railway (private line) uses thick class G steel wheels and turns them until the thickness is reduced to 25 mm.

Question 14. — *List the defects such as shelling, scaling, radial cracks or others? Are these defects more or less frequent with solid than with tyred wheels?*

See reply to Question 5.

C. — TYRED WHEELS.

Question 15. — *What quality of metal of tyres (chemical analysis and physical characteristics, method of manufacture and especially type of heat treatment)?*

Question 16. — *What are the measures that you have adopted to reduce to a minimum the risk of loose tyres? (State of surface after machining, diameters of the wheel centres and tyres in contact before mounting, system of heating tyres, etc.). Do you weld at the rim to prevent loose tyres?*

Question 17. — *What are your specifications regarding the minimum thickness of tyres*

TABLE 19.

Minimum thickness of railcar tyres on tyred wheels.

Administration	Type of axle and kind of service	Max. speed	Minimum tyre thickness	
			Out of shop after last turning in mm	When worn to scrapping size in mm
BELGIUM. *S. N. C. B.*	Light railcars	—	25	20
	Heavy railcars	—	40	35
S. N. C. V.	All railcars	85	35	25
DENMARK. *State Railways*	Axle load < 10 t	—	—	27
	Axle load between 10 and 15 t	—	—	32
	Axle load ⩾ 15 t	—	—	37
FRANCE. *S. N. C. F.*	All tyred railcar wheels (max. load 12 t)	140	30	25
Gafsa Railways	All axles	55	48	43
NETHERLANDS. *Netherlands Railways*	All axles	—	38	35
NORWAY. *State Railways*	Main line railcars	—	40	—
	Secondary line railcars	—	25	—

according to the load or maximum speed permitted for vehicles (minima both after repair and in service)?

Question 18. — *When wheels have flats do you repair by building up by welding and making good the tyre surface by grinding or turning?*

Question 19. — *In addition to choice of metal and its treatment do you employ other methods to reduce tyre wear (e. g. lubricating flanges or rails)?*

The metal of the tyres, its treatment, methods of repair, etc., are the same as for other rolling stock. The limits of wear are given in Table 19.

Question 20. — *Have you found with locomotives that the lateral displacement of the axles influences tyre wear?*

Question 21. — *Have you proved that lessening of hunting (particularly lessening the rotation of the bogie round its pivot) reduces tyre wear?*

No observation on this matter has been received.

Question 22. — *Have you tried or do you use independent wheels? What has been your experience with these wheels regarding tyre wear?*

Amongst the rare examples of the application of this type of wheel, we can mention certain carrying axles of the Bugatti railcars of the S. N. C. F. The elastic wheels with metal tyres are mounted free on fixed axles. These axles with independent wheels have given no trouble. Independent wheels with pneumatic tyres are also used on the Michelin railcars.

D. — AXLE BOXES.

a) Roller bearing boxes.

Question 23. — *Do you use roller bearings? If so, kindly say what results have been obtained regarding :*

a) *Number of hot boxes;*

b) *Maintenance costs;*

c) *State period between lubrication and inspection.*

Very many applications of roller bearings to railcars have been made. Table 20 gives the characteristics of the bearings and the applications. Both S. K. F. and *Timken* boxes are in use.

Most applications are of double bearing outside boxes : on its new standardised 600 HP railcars, the S. N. C. F. is fitting inside boxes with one bearing with two sets of rollers forming a self-centering box.

Generally speaking roller bearing axle boxes are giving satisfaction.

Heating is practically non-existant for example there has been one case on the 704 S. K. F. roller bearing boxes lubricated with grease and three heating cases on the 48 *Timken* roller bearing boxes with oil lubrication. These latter boxes are fitted on the very high speed railcars.

Question 24. — *Have you found any difficulties due to the use of axle boxes of this type? Please indicate (fractures and wear of details, damage through rough shunting, etc.).*

The S. N. C. F. and the Netherlands Railways report fissures in the journals with roller bearing axleboxes in line with the sleeve and ascribed to the too sharp edges of the sleeve in question.

After rounding the edges of the sleeve the Netherlands Railways report the breakages have disappeared (see fig. 29). The S. N. C. F. has also rounded them off but without obtaining such net results. The diameter of the journal appears to be a factor and should be reinforced at the same time (Table of Question 25 shows the increase by 120 to 150 mm introduced by the S. N. C. F. in connection with its 600 HP railcars).

As regards the costs of maintenance and the period between greasing, the data supplied is the same as that for the other railcars and especially the electric railcars (see 4th Part).

Question 25. — *What type of roller bearing box do you use (cylindrical, conical or roller bearings)?*

Table 20 gives particulars of the S. K. F. and *Timken* or similar roller bearing boxes used on railcars.

The Table 20 gives all the information asked for.

Question 28 and 29. — No information worth having has been mentioned.

b) Axle boxes with plain bearings.

Question 30, 31 and 32.

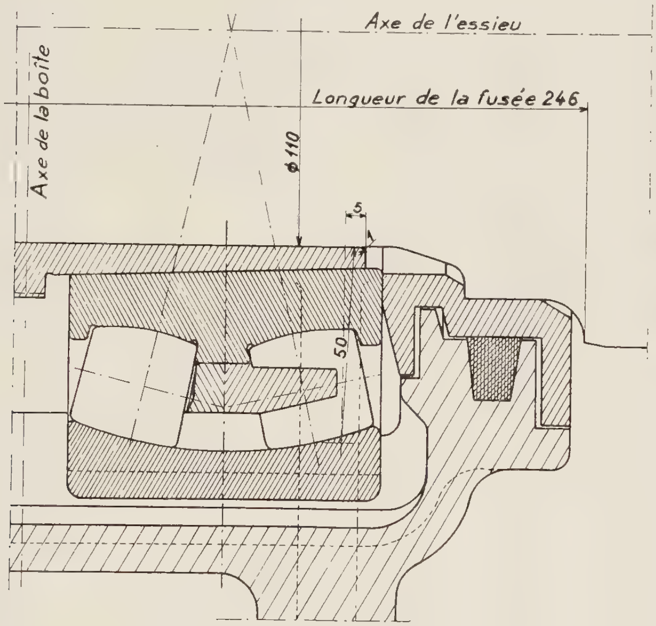

Fig. 29. — Section of the conical locking ring of S.K.F. roller bearing, showing the rounded edge of the S.K.F. ring (Detail of drawing nº VP 15518 — Netherlands Railways)

Explanation of French terms. — Axe de la boîte = Centre line of the box. — Axe de l'essieu = Wheel centre line. — Longueur de la fusée = Length of journal.

Question 26. — *What type of protection do you use against the penetration of dust and water into the interior of the box?*

No other information than that given when considering other rolling stock.

Question 27. — *What are the loads per axle and the speeds permitted for the boxes you use? Give principal dimensions, catalogue number, drawing, etc.?*

Athermos boxes are used by the S.N.C.B. and information concerning these boxes has been given for other rolling stock.

c) Improvements to ordinary boxes with plain bearings.

Question 33, 34 and 35.

These questions do not apply to railcars

TA

Characteristics of SKF bearings with spherical rollers used on railcars in se

Catalogue number of bearing	Number of bearings per box	Projected length of the bore of the bearing in mm	Outside diameter of the bearing in mm	Min. dia. (1) of the bore of the bearing for shrinkage fit in mm	Diameter of journal in mm
22 318 K	2	64	190	90	85
22 318 K	—	64	190	90	85
22 320 K	—	73	215	100	95
22 320 K	1	73	215	100	95
23 220 K	2	60	180	100	95
22 322 K	1	80	240	110	100
I 37 602	2	73	220	120	110
22 324 K	1	86	260	120	110
22 324 K	1	86	260	120	110
22 324 K	—	86	260	120	110
22 224	2	58	215	120	120
22 326 K	—	93	280	130	120
I— 116933	1	—	—	—	—
I— 61 190	2	—	—	—	130
I— 37 603	2	80	240	130	125
I— 26 305	1	93	280	150	150
			Characteristics of bearings with tapered rc		
866/853	2 with single row of rollers	57	190	90	90
30219/30219B fitted hot	1 with quadruple row of rollers	150	170	95	95
862/853 fitted hot	2 with single row of rollers	57	190	95	95
30 220 fitted hot	2 with single row of rollers	164	190	95	95
Timken	—	—	280	130	130

(1) When bore is tapered.

r construction (classed by increasing diameter of journal).

ameter ie wheel mm	Maximum speed of vehicle in km/h	Maximum axle load in t	Railcars on which this type of bearing is used		
			Administration	Type	Number
860	120	9.8	*S. N. C. F. (France)*	*Renault VH1* (220 H.P.)	15
720	60	10.7	*S. N. C. B. (Belgium)*	—	—
970	85	9.7	— d° —	—	—
860	120	9.5	*S. N. C. F. (France)*	*De Dietrich* (210 H.P.)	31
860	120	9.8 10.5	— d° —	*Renault VH2* and *ABJ 1, 2, 3, 4* (300 H.P.)	60
860	120	11.5 12.5	— d° —	*De Dietrich* (320 H.P.) *ADN* 280 H.P.	42 22
860	120	13.2	— d° —	*Renault ADX* and *ADP* (500 and 600 H.P.)	37
860	120	15 13.5	— d° —	*Standard* 600 H.P. *De Dietrich* 500 H.P.	52 6
900	125	12	*Netherlands Rys.*	—	—
970	85	14.6	*S. N. C. B. (Belgium)*	—	—
860	110	12.8	*S. N. C. F. (France)*	*Decauville* 600 H.P.	17
970	155	16	*S. N. C. B. (Belgium)*	—	—
950	125	18	*Netherlands Rys.*	—	—
—	120	17	*Danish State Rys.*	—	—
—	120	15	*Norwegian State Rys.*	Triple rakes type 8	4
860	120	13.5	*S. N. C. F.*	Standardised 600 H.P.	under construction

en and others) used on railcars.

860	120	10	*S. N. C. F. (France)*	*Renault VH2* and *ABJ 1* and *2* (300 H.P.)	115
860	120	11	*S. N. C. F. (France)*	*Renault AEK* (300 H.P.)	20
860	120	10.5	— d° —	*Renault ABJ3* (300 H.P.)	27
860	120	10.5	— d° —	*Renault ABJ4* (300 H.P.)	18
—	150	18.5	*S.N. C. B. (Belgium)*	—	—

on which plain bearings are very rarely used.

d) Present tendencies as to the selection of the type of box.

Question 36. — *Set out the different categories of locomotives and rolling stock, and the various types of service which govern the choice of the type of boxes to be adopted, showing the reasons.*

Roller bearing boxes whether S. K. F. type or with cylindrical or taper rollers are fitted to the large majority of railcars in use on the different Railways.

Today it can be said that all new railcars are so fitted (S. N. C. B., S. N. C. F., Netherlands).

Up to the present the boxes were of the outside type. It is interesting to note that the S. N. C. F. standardised 150, 300 and 600 HP railcars under construction have the boxes on inside journals; this arrangement makes it possible to lighten the bogie frame and make the brake gear, arranged outside the frame, more accessible. The one piece wheel is fitted to the axle on a tapered seat and the wheel can be replaced by a simple jack instead of the body of the vehicle having to be lifted.

E. — WEAR RESISTING AND ANTI-FRICTION METALS.

Question 37, 38 and 39.

The information received is the same as that given for other rolling stock.

Question 40. — *Have you adopted any special arrangements to avoid reciprocal friction between the different details (e. g. guiding by articulated links on silent block, etc.)?*

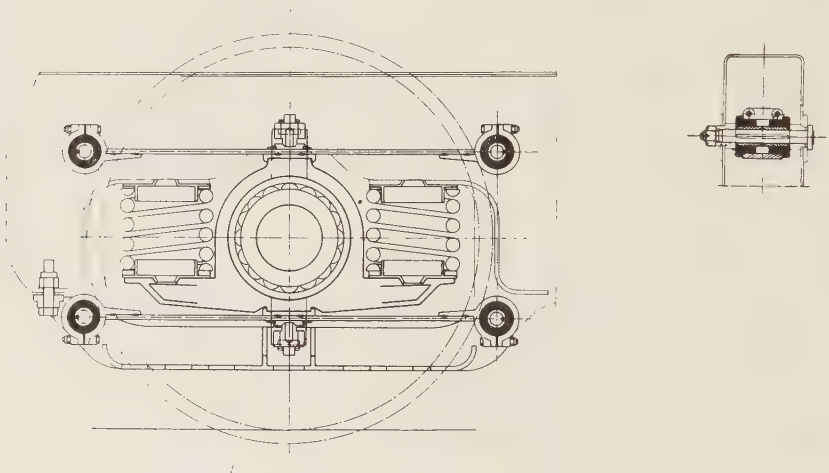

Fig. 30. — Frictionless guiding by flexible plates and silent blocks of the axles of the standardised 300 and 600 H.P. railcars being built for the S. N. C. F.

The S. N. C. F. and Norwegian Railways alone report using on existing rolling stock or on stock being built, arrangements to suppress the rubbing of the axleboxes on the guides.

The Norwegian Railways on their numbers 6 and 7 types of railcars guide the axlebox by rods and silent-block bushes (an arrangement also noted in connection with electric locomotives in the 2nd Part).

The S. N. C. F. 300 and 600 HP standardised railcars under construction are fitted with a transmission arrangement by

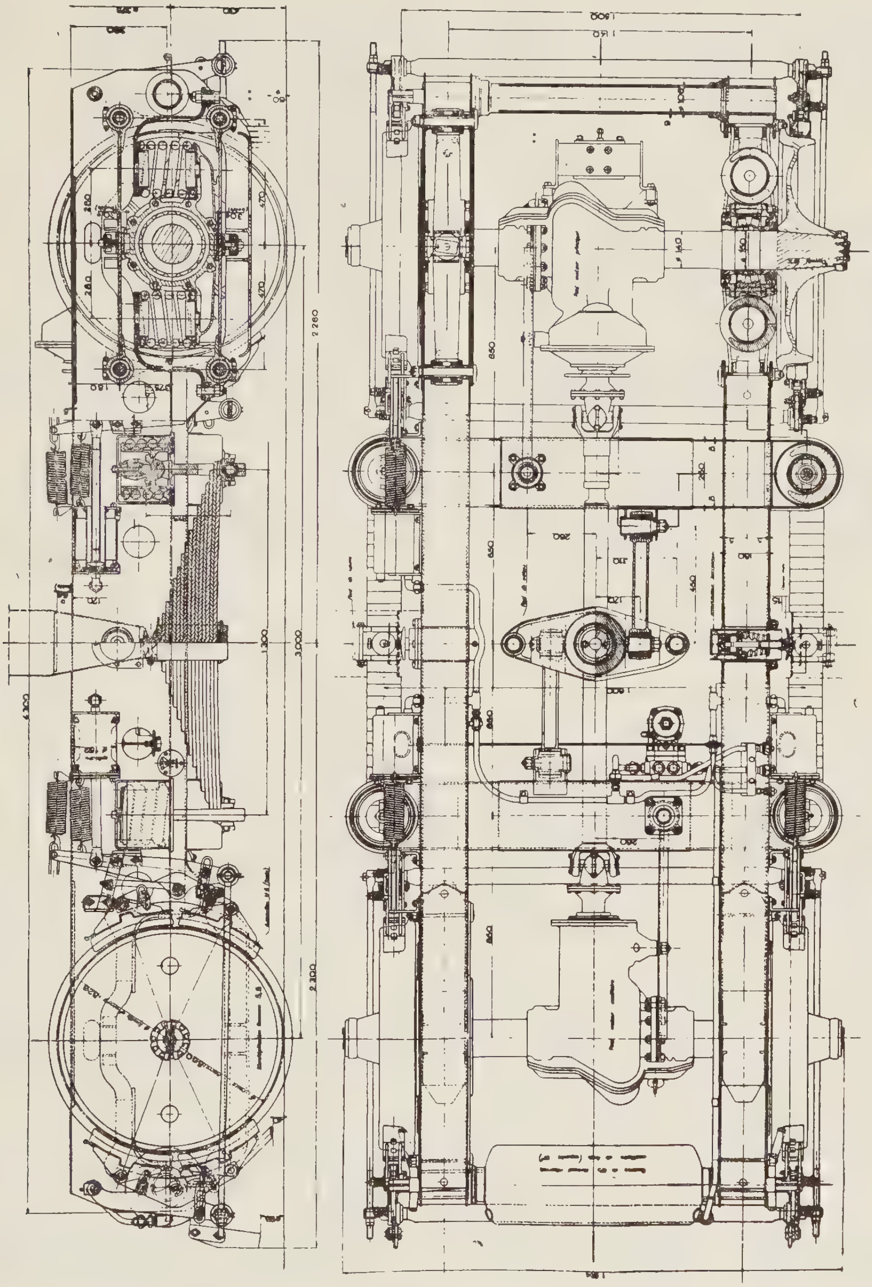

Fig. 31. — Bogie of 600 HP standardised S. N. C. F. railcar (under construction).

flexible plates connecting the axleboxes to the frame as shown in figure 30. In addition, the general design of the bogies such as those under the 600 HP railcars shown in figure 31 suppresses rubbing surfaces to the greatest possible extent.

F. — SPRINGS.

Questions 42, 43, 44, 45 and 46.

The information sent in includes no particular data relative to railcars.

Question 47. — *Do you use rubber springs (for suspension, for shock and for drawgear, etc)? What are the results obtained?*

The use of rubber springs has been little developed in the spring gear of railcars so far, on which the conjugated use of coiled springs and snubbers is more usual. However rubber is used for the buffing gear.

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FOURTH PART.

Electric motor coaches.

A. — GENERAL.

Question 1. — *State the regulations which govern maintenance and periodic repair of locomotives, carriages, wagons, rail cars, etc., What are the conditions of wear of details (e. g. the hollowness of tyre before removal) which have led to the fixing of these regulations?*

Question 2. — *Can it be said generally that mileage between repairs has been increased with improved modern rolling stock and locomotives? If possible give examples.*

The electric rail motor coaches are maintained and repaired on the same lines as the electric locomotives. The mileages between tyre turning are :

S.N.C.B., Denmark, Norway : 100 000 km;

S.N.C.F. : 100 000 to 140.000 km for main line motor coaches; 140 000 to 160 000 km for suburban motor coaches.

For local lines the figures are :

- French Nord Light Railways (Valenciennes-France system) the tyres are re-turned every 40 000 km;
- S. N. C. V. (Belgium) confirm, though without any information as to mileage, that tyre wear determines the time between repairs;
- Metropolitan (Paris) turn tyres after 70 000 km at each heavy repair.

Generally, the replies do not report that any increase in mileage between repairs has been obtained recently. The French Light Railways (Nord) give interesting mileage figures. The mileage between repairs before the war was 30 000 km and has been increased to 40 000 km.

These Railways are endeavouring to increase the mileage between repairs to 50 000 or 60 000 km by building up the tyre flange, altering the axle bearing carrying the motor, and by using roller bearings.

B. — ONE PIECE WHEELS.

Question 4. — *Have you had experience with solid wheels?*

Question 5. — *If so, what are the results which you have obtained or hope to obtain by using solid wheels from the point of view of regularity of the service? What are the advantages and disadvantages already established?*

One piece wheels are in use in Belgium, France, Holland and Switzerland. The value of these wheels has been dealt with under Electric Locomotives and Carriages. The freedom from tyre movement, and the reduction of weight are especially valuable in the case of vehicles required to have high acceleration and retardation.

The observations made are :

- S. N. C. F. has the following vehicles fitted :

  207 motor coaches at 750 V in use on the St. Lazare suburban service put into use in 1924 to 1930.

The wheels are 1 100 mm diameter, the speed 80 km/h. the rim thickness 78 mm in 75 kg/mm² forged carbon steel;

20 double motor coaches and 5 main line motor coaches at 1 500 V on the Paris-Le Mans line built in 1938. Wheel diameter = 900 mm, speed 130 km/h., tyre 30 mm thick, in Cr-Mo steel of 110 kg/mm² quality.

These latter at first had many cases of scaling or flaking. Ordinary steel with thicker rims (60 mm) has given better results. One piece wheels will be used on all future stock and notably on rail motor coaches for the Paris suburban line (Gare de Lyon) to be electrified by the end of 1950;

— the S. N. C. B. has fitted one bogie only with cast steel wheels as a test. Cracks developed after a short mileage;

— the Netherlands Railways carried out tests in 1935-1936 and report that there is hardly any movement on tyred wheels and that one piece wheels in their opinion are not needed. They found more flaking with them too especially with drums or disc brakes. On the corrugated form of wheel centre cracks were found owing to the excessive rigidity of the wheel (see 3rd Part — Question 5);

— the C. F. F. are satisfied with the application made to their motor coaches. The speeds are between 90 and 100 km/h. (maximum 125 km/h.) and exceptionally 150 km/h. The wheels are made of 80 kg/mm² carbon steel and the rims heat treated to give 100-110 kg/mm².

Question 6. — *The same question from the cost point of view.*

The kind of steel selected, the design of the wheel (thin rim or thick rim), the quantity ordered are all factors affecting the cost price. Possibly the different opinions given above as to their value are explained by the differences in the nature of these factors. No detailed balance sheet has been supplied.

Question 7. — *Do you use solid wheels on vehicles running at high speeds?*

See Question 4 for the speeds being run.

Question 8. — *Do you use them on braked vehicles (braking on running surface, on brake drum, or on the wheel centres)? What material is used for brake shoes? What advantages and disadvantages have been established?*

The S. N. C. F. report its motor coaches are being fitted with the ordinary brake and in addition, for high speed vehicles, a rheostat brake.

The Netherlands Railways (see Question 4) fitted some motor coaches with drum and disc brakes and found much flaking of the treads on the wheels.

Question 9. — *What metal is used for solid wheels (chemical analysis and physical characteristics)?*

Question 10. — *Do you use special methods of manufacture in order to obtain the appropriate characteristics of the metal in the different parts of the wheel?*

The metal used is shown under Question 4 and is generally 80-90 kg/mm² ordinary carbon steel.

The C. F. F. use carbon steel treated to give 110 kg/mm² on the tread (see the process described under one piece wheels for carriages in the 5th Part). The S. N. C. F. report a test of surface hardening on steam locomotives (see 1st Part).

Question 11. — *Can the solid wheels which you use be re-profiled, by the depositing of metal, by turning, etc., and what are the thickness limits in each case?*

The wheels are generally turned up. The C. F. F. and French Nord Light Railways report the flanges are regularly made good by building up by welding.

The limits of wear, minimum thickness, on the S. N. C. F. for ordinary carbon steel wheels are :

32 mm for the 750 V motor coaches on the Paris-St. Lazare suburban line;

34 mm for the 1 500 V motor coaches on the Paris-Montparnasse suburban line;

24 mm for the 1 500 V on the main line Paris-Le Mans.

The Netherlands, C. F. F., Rhaetian and Emmental-Thun Railways fit tyres to one piece wheels worn to the limit.

The S. N. C. F., although this was done in the war owing to the shortage of wheels, do not do so now.

C. — TYRED WHEELS.

Question 15. — *What quality of metal of tyres (chemical analysis and physical characteristics, method of manufacture and especially type of heat treatment)?*

Question 16. — *What are the measures that you have adopted to reduce to a minimum the risk of loose tyres? (State of surface after machining, diameters of the wheel centres and tyres in contact before mounting, system of heating tyres, etc.). Do you weld at the rim to prevent loose tyres?*

Question 17. — *What are your specifications regarding the minimum thickness of tyres according to the load or maximum speed permitted for vehicles (minima both after repair and in service)?*

Question 18. — *When wheels have flats do you repair by building up by welding and making good the tyre surface by grinding or turning?*

Question 19. — *In addition to choice of metal and its treatment do you employ other methods to reduce tyre wear (e. g. lubricating flanges or rails)?*

The information on tyred wheels of motor coaches is the same as for the other stock. Table 21 gives the limits of wear.

Question 20. — *Have you found with locomotives that the lateral displacement of the axles influences tyre wear?*

Question 21. — *Have you proved that lessening of hunting (particularly lessening the rotation of the bogie round its pivot) reduces tyre wear?*

The C. F. F. report that on the 2 or 3 bogie motor coaches they use successfully transversal couplings conjugating the oscillations of the bogies. On the meter gauge coaches on the Brünig line the simultaneous introduction of flange lubrication and transversal couplings raised the mileage of the tyres between turnings from 6 000 km to 100 000 km. Flange lubrication alone would have increased it only to 20 000 km (see fig. 24).

Question 22. — *Have you tried or do you use independent wheels? What has been your experience with these wheels regarding tyre wear?*

No case of the use of independent wheels has been reported.

D. — AXLE BOXES,

a) Roller bearing boxes.

Question 23. — *Do you use roller bearings? If so, kindly say what results have been obtained regarding :*
1) *Number of hot boxes;*
2) *Maintenance costs;*
3) *State period between lubrication and inspection.*

Table 22 summarises the applications reported and shows the use of these bearings to be general on motor coaches. The Railways agree the results are very satisfactory, heating having been practically eliminated and failures very rare.

The information on costs and periods between oiling and repairs is the same as

TABLE 21.

Minimum thicknesses of tyres on electric motor coaches.

ADMINISTRATION	Type of axle and kind of service	Max. speed	Minimum tyre thickness: Out of shop after last turning in mm	Minimum tyre thickness: When worn to scrapping size in mm
BELGIUM	All motor coaches :			
S. N. C. B.	carrying axles,		35	30
	driving axles		40	35
S. N. C. V.	All axles of motor coaches	85	35	25
FRANCE *S. N. C. F.*	All axles of motor coaches (maximum load : 18 t)	130	45	40
Paris Transport Board	*City lines* (Métro) :	50		
	carrying axles : 8 t		27	25
	driving axles : 13 t		32	30
	Sceaux line :	80		
	carrying axles : 13 t		32	25
	driving axles : 18 t		48	40
Ch. de fer Economiques du Nord (Réseau de Valenciennes)	Axles of motor coaches loaded : 10 t		—	23
NETHERLANDS *Netherlands Railways*	All modern motor coaches		38	35
	Old motor coaches		43	40
NORWAY *State Railways*	All motor coaches without taking into account either load or speed.		25	—
SWITZERLAND *C. F. F.*	All motor coach axles	—	40	—
Emmental-Thun	All motor coach axles (maximum : 14 t)	90	40	—
Rhaetian Railway	All motor coach axles (maximum : 7 t)	55	30	25

TABLE 22.

Roller bearing boxes used on electric motor coaches.

ADMINISTRATION	Number of types of motor coaches fitted with roller bearing axle boxes	Types of boxes fitted	Max. speed	Mileage without defect in km
BELGIUM *S. N. C. B.*	74 bogie motor coaches	Outside SKF roller bearing boxes	120 and 140	
BELGIUM *S. N. C. V.*	Motor coaches	Outside SKF boxes with cylindrical roller bearings	85	
DENMARK *State Railways*	All motor coaches	Outside SKF boxes with 2 bearings	90	
FRANCE *S. N. C. F.*	20 suburban motor coaches with bogies (axle weight : 17 and 18 t)	Outside SKF boxes with 2 bearings	90	Maximum mileage per vehicle 750 000
	20 double 3 - bogie outer suburban motor coaches (axle weight : 12.5 t)	d°	130	750 000
	5 main line bogie motor coaches (axle weight : 10 t)	d°	130	700 000
Paris Transport Board	60 motor coaches for the Sceaux line (axleweight : 15.5 t)	Outside SKF boxes with 1 bearing forming self aligning box	80	
NETHERLANDS *Netherlands Railw.*	All motor coaches	Outside SKF boxes with 1 or 2 bearings	110 and 125	
NORWAY *State Railways*	All motor coaches	Outside SKF boxes with 2 bearings	75 and 120	Total mileage 25 000 000
SWITZERLAND *Rhaetian Railways*	Motor coaches	Outside SKF boxes with 1 bearing forming self aligning box. Boxes with cylindrical roller bearings.	55	
SWITZERLAND *Emmental-Burgdorf-Thun Railway*	Motor coaches	SKF or *Winterthur* Locomotive Works boxes	90	
SWITZERLAND *C. F. F.*	Fast single, double or triple motor coaches.	Outside SKF boxes with 1 or 2 bearings	125 exceptionally 150	

for other stock. The Paris-Metropolitan reports that on the 1 500 V overhead system electrified Sceaux line the boxes are taken down after 200 000 km and that the annual repairs costs is 625 francs per box. The French Nord Light Railways (Valenciennes lines) report a saving in current consumption of 16 % — a figure confirmed by tests over a number of years. The Metropolitan (Paris) also estimates the friction of the *Athermos* box to be as low.

Question 24. — *Have you found any difficulties due to the use of axle boxes of this type? Please indicate (fractures and wear of details, damage through rough shunting, etc.).*

Generally, only a few failures due to broken or cracked races and defective assembly have been reported. The S.N.C.F. alone reports cracks in axle journals. The Netherlands Railways have found such cracks attributed to too sharp corners of the sleeves which ceased when the corners were well rounded (see fig. 28).

Question 25. — *What type of roller bearing box do you use (cylindrical, conical or roller bearings)?*

See Table mentioned on Questions 23 and 27.

Question 26. — *What type of protection do you use against the penetration of dust and water into the interior of the box?*

The information is the same as for other stock (1st and 2nd Parts).

Question 27. — *What are the loads per axle and the speeds permitted for the boxes you use? Give principal dimensions, catalogue number, drawing, etc.?*

Table 23 gives particulars of the boxes fitted.

Question 28. — *What is the system of mounting the rollers on the journal? What are the advantages and disadvantages of the system used?*

All the applications reported have taper sleeves.

Question 29. — *Do you use special arrangements to prevent electric current passing through the roller bearings (current for traction or heating)?*

Several Administrations use special devices (R. A. T. P., Danish, Netherlands, Norwegian, C. F. F.).

On the Norwegian Railways, a brush fastened on the frame rubs against a copper disc on the axle. On the motor coaches on the Sceaux line of the R. A. T. P. the boxes are insulated from the bogie frame by axle box guides lined with « céloron » and by insulating packings under the coiled springs. A bond connects the body frame to the traction motor and to the brasses of the motor bearings.

The S. N. C. V. (Belgium) used this arrangement when introducing roller bearing boxes but gave it up as experience showed that the roller bearings could stand without much harm a current of about 100 A. The S. N. C. F. does not use any such fitting.

b) Axleboxes with plain bearings.

Questions 30, 31 and 32.

Nothing to report other than that given for other stock.

c) Improvement of ordinary boxes with plain bearings.

Questions 33, 34 and 35.

Nothing more to report for this than already given for other rolling stock.

d) Present tendencies as to the choice of axlebox.

Question 36. — *Set out the different categories of locomotives and rolling stock, and the various types of service which govern the choice of the type of boxes to be adopted, showing the reasons.*

TABLE 23.

Characteristics of SKF roller bearings used on electric motor coaches.
(classified by increasing diameters of journals.)

Catalogue number of bearing	Number of bearings per box	Projected length of the bore of the bearing in mm	Outside diameter of the bearing in mm	Minimum diam. (1) of the bore of the bearing for shrinkage fit in mm	Diameter of journal in mm	Diameter of the wheel in mm	Maxim. speed of vehicle in km/h	Maxim. axle load in t	Motor coaches fitted with this type of bearing: Administration	Type and series	Number
22 320 K	1	73	215	100	95	750	55	6 to 7 t	*Chemins de fer Rhétiques* (Switzerland)	—	—
I-37 602	2	73	220	120	110	900	130	12 t	*S. N. C. F.* (France)	Main line motor coaches with bog.	5
I-35 156	2	80	240	120	110	—	75	13	*Norwegian State Railways*	—	—
I-35 156	2	80	240	120	110	1000	110	12.2	*Netherlands Railways*	—	—
22 324 K	1	86	260	120	110	900	125	10	*C. F. F.* (Switzerland)	Motor coaches with bogies	9
22 324 K	1	86	260	120	110	1000	120	6.2	*S. N. C. B.* (Belgium)	Motor coaches with bogies	74
22 326 K	—	93	280	130	120	1020	140	10.6			
22 326 K	1	93	280	130	120	1000	110	11.8	*Netherlands Railways*	—	—
22 326 K	1	93	280	130	120	—	80	15.6	*Régie autonome des Transports Parisiens*	Motor coaches of Sceaux line	60
I-37 906	2	86	260	130	120	—	90	15.5	Denmark	—	—
I-37 603	2	80	240	130	125	—	120	13	*Norwegian State Railways*	—	—
22 328 K	2	102	300	140	125	—	125(150)(2)	13.2	*C. F. F.* (Switzerland)	Double and triple fast mot. coaches	5
I-37 604	2	86	260	140	130	950	130	15	*S. N. C. F.* (France)	Double suburban mot. coaches	20
22 330 K	2	108	320	150	140	1100	90	19	*S. N. C. F.* (France)	Suburban mot. coaches	20
I-37 605	2	93	280	150	140	1000	110	17.7	*Netherlands Railways*	—	—
22 334 K	1	120	360	170	160	1000	110	17.7	— d° —	—	—
I—116 933	1	—	—	—	—	950	125	18	— d° —	—	—

The general tendency appears to use roller bearings on long distance motor coaches for security against overheating and for their lower costs of repairs. For suburban lines boxes with continuous oil circulation are often given preference owing to the high cost of roller bearings and the less upset caused by overheating by the termini being near (R. A. T. P., Nord Light Railways). The S. N. C. V. (Belgium) has however adopted roller bearing boxes.

E. — WEAR RESISTING AND ANTI-FRICTION METALS.

Questions 37 to 41.

Apart from the information given for other rolling stock the only additional particular points are the following :

- axlebox guides lined with « céloron » on the R. A. T. P. on the Sceaux line motor coaches and « Mintex » on the fast Norwegian motor coaches;
- the Nord Light Railways designed a special layout to limit the wear of the bearings of nose suspended motors. The side wear of the bearings due to the lateral loads transmitted by the axle and the radial wear of the brass bearing surfaces were thought to be accelerated by the introduction of dust and liquid mud picked up from the groove in the rails by the wheel flanges which after running along the spokes penetrated the ends of the bearings and the wheel brasses. To stop this deflectors were fitted on the bosses of the wheels : in addition to reduce the wear of the ends of the brasses these were fitted with « céloron » (after inferior results of with « ferrodo »). « Céloron » bearings too have given good results on trial but they are not being used as they cost too much.

F. — SPRINGS.

Questions 42 to 47.

Nothing to add to that reported in connection with other stock. The S. N. C. V., (Belgium) it may be noted, used a mixed spring gear of rubber in parallel with coiled springs.

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FIFTH PART.

Carriages and wagons.

A. — GENERAL

Question 1. — *State the regulations which govern maintenance and periodic repair of locomotives, carriages, wagons, rail cars, etc., What are the conditions of wear of details (e. g. the hollowness of tyre before removal) which have led to the fixing of these regulations?*

a) *Carriages :*

The repairs to the running gear are carried out at pre-determined intervals. Some Railways carry out repairs on a mileage basis as we shall show later.

Apart from axle box examination every six months for the RIC carriages as agreed internationally the coaches are lifted and the tyres turned up once a year on main line metal coaches (S. N. C. B., S. N. C. F., Netherlands, C. F. F.) and every 15 to 24 months for the rest of the stock (15 months on the Netherlands, 2 years on the S. N. C. B. and C. F. F.).

The Railways repairing coaches on mileage are :

Danish : 70 000 km for ordinary boxes; 80 000 km for rolling bearing boxes;

Moroccan : 120 000 km for boxes with brasses; 150 000 km for roller bearing boxes;

Norwegian : 55 000 km-carriages and wagons exceeding 70 km/h.; 65 000 km other vehicles.

S. N. C. F.

While, generally, the S. N. C. F. bases repairs on the time on service, one of its regions, the South-West, takes mileage into account.

The Netherlands Railways point out that the mileage of trailers hauled by electric locomotives is much increased and the 12 months period is too long; they intend to reduce it to 6 or 9 months.

The above figures suggest that the Danish and Moroccan Railways have been able to increase the mileage by fitting roller bearings.

As regards *permissible tyre wear,* the S. N. C. F. limits the depth of flange to 33 mm when lifting and to 30 mm at heavy repairs in the main workshops.

b) *Wagons :*

Besides the international requirements of repairs to ordinary wagons at 3 years and 18 months for « S » wagons, the wagons are lifted and the tyres done up every six years.

Question 2. — *Can it be said generally that mileage between repairs has been increased with improved modern rolling stock and locomotives? If possible give examples.*

The progress in the construction of modern bogie metal wagons is mainly in the running gear, the design of the bogie, and the reduction of weight.

The S. N. C. F. has no information with figures so far.

The C. F. F. report their light vehicles between two overhauls run three or four times the mileage of the rest of the stock. The daily mileage varies between 600 and 1 000 km. As Question 3 will show the C. F. F. has endeavoured to reduce repair costs by a bogie design suppressing all parts subject to wear.

The S. N. C. B. and the Netherlands Railways report that modern stock is worked more intensively than the old so that no comparison for equal service can be given.

Question 3. — *When ordering new rolling stock and locomotives, is consideration given to maintenance costs in the specification, and if when ordering modern stock are endeavours made to reduce these costs? Indicate if the Railway administration endeavours to obtain similar results by the modification of stock in service.*

The reply of the S. N. C. B. which sums up the opinion of all the Railways is given below.

New rolling stock is not ordered to save repair costs but its design reflects the application of the experience with other stock to reduce such costs.

Stock in service is altered in some instances to reduce maintenance.

As an example the C. F. F. point out to get the same results as from the new lightened stock (see Question 2) they are replacing the plain bearings on 58 R. I. C. coaches by roller bearings. The Netherlands Railways also quote the application of roller bearings.

B. — ONE PIECE WHEELS.

Question 4. — *Have you had experience with solid wheels?*

One piece wheels are used by many Railways and are made of cast or forged steel on carriages and cast iron on wagons.

Table 24 gives particulars thereof.

Question 5. — *If so, what are the results which you have obtained or hope to obtain by using solid wheels from the point of view of regularity of the service? What are the advantages and disadvantages already established?*

Question 6. — *The same question from the cost point of view.*

One piece wheels were introduced to suppress loose tyres on long runs abroad (R. I. C. coaches of the C. F. F.). They are valuable as they are lighter.

Coaches.

The results differ as between Railways.

The largest experience is that of the

TABLE 24.

Application of one piece wheels to carriages and wagons.

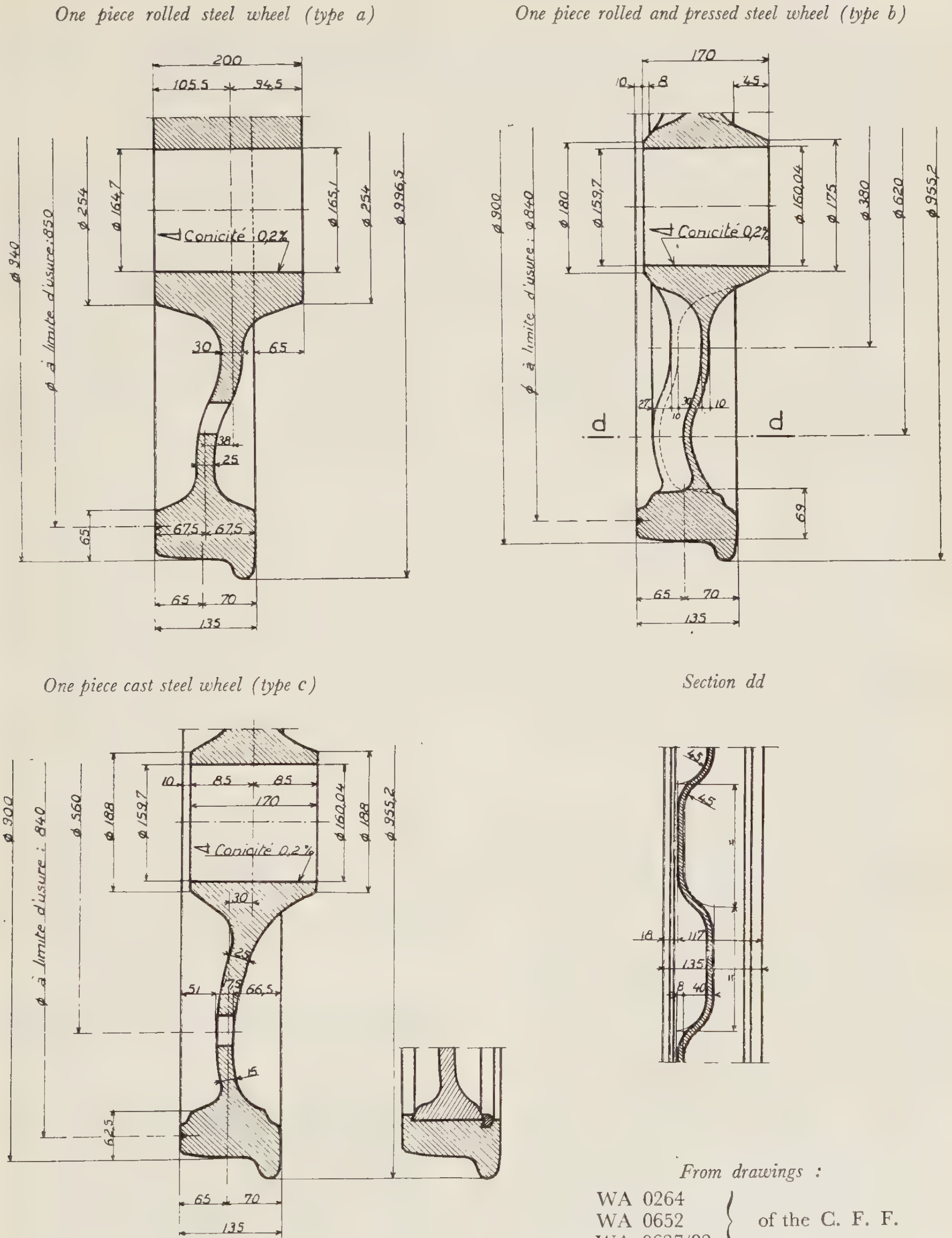
ADMINISTRATION	Stock with one piece wheels	Wheel diameter (mm)	Rim thickness (mm)	Max. speed (km/h.)	Kind of steel and remarks
BELGIUM *S. N. C. B.*	10 RIC bogie coaches fitted experimentally with one piece wheels in 1940	—	—	—	Rolled steel. All these wheels withdrawn.
	6 200 Canadian built wagons put into service in 1940	—	—	—	Cast iron. All these wheels withdrawn.
Matadi to Léopoldv. Railways (OTRACO)	Some American built wagons with one piece wheels				Die cast iron. When worn replaced by tyred wheels.
FRANCE *S. N. C. F.*	45 light vehicles with streamlined bodies of the Western region 1936,	920	73	130	Forged carbon steel class GG (ST no. 301).
	1 bogie fitted experimentally with English made one piece wheels	920	75	130	Forged or rolled hard steel *Steel Peech and Tozer* wheels.
	42 500 - 2 axles wagons and 1 500 flat bogie wagons of American build with castiron one piece wheels	915	75		Chilled cast iron.
Morocco Railways	American wagons				Cast iron.

TABLE 24 *(continued)*.

Application of one piece wheels to carriages and wagons.

ADMINISTRATION	Stock with one piece wheels	Wheel diameter (mm)	Rim thickness (mm)	Max. speed km/h	Kind of steel and remarks
Indochina extension Railways	A small number of wagons with one piece wheels in service				
HOLLAND *Netherlands Railways*	American Army wagons				Die cast iron.
	About 800 open 2 axle wagons fitted with one piece wheels experimentally				Forged rolled steel. No conclusions yet given.
SWITZERLAND *C. F. F.*	190 RIC bogie vehicles put into service from 1934 to 1943	940	65	120	Rolled steel.
	90 light vehicles put into service from 1937 to 1941	900	42.5	125	Rolled and pressed steel. Replaced by tyred wheels.
	70 light steel vehicles put into service from 1945 to 1949	900	42.5	125	Cast steel of Swiss manufacture.
Rhaetian Railways	Use stock with one piece wheels.				Cast steel.
Emmental-Thun Railways	(no particulars given)				Siemens Martin steel

(1) The thickness is defined as half the difference between the diameter at the rolling circle and the inside diameter of the tyre measured on the outside face of the tyre.



From drawings :
WA 0264
WA 0652 } of the C. F. F.
WA 0627/82

Fig. 32. — One piece steel wheels used on light-weight vehicles of the C. F. F. The profile of the rim types *b* and *c* its designed to lend itself readily to the fitting of a tyre when worn.

C. F. F. which is very satisfied with them. Besides freedom from getting loose they last longer as there is less wear on the tread (see kind of metal Questions 9 and 10). This greater hardness makes it necessary to use special machine tools to grind the treads. The flaking and scaling recorded is no greater than on tyres. The average wear on the tread is 3 mm per annum on the diameter.

Comparing the different qualities of steel, the C. F. F. report that the one piece wheels *rolled* from 70-85 kg/mm² *steel* on their R. I. C. coaches have behaved very well. The rolled and pressed wheels of 80-90 kg/mm² steel with tread and flange hardened to 100 kg/mm² developed circular cracks in the body of the wheel near the rim. The *cast steel wheels* made in Switzerland when one piece forged wheels were unobtainable and which went into service in 1946-1949 have developed no defects (see fig. 32 *a*, *b*, *c*).

As regards economy, the C. F. F. finds the costs lower than for tyred wheels. Practically all the one piece wheels under the 190 R. I. C.. coaches are in use at the present time and as there are no loose tyres the time the stock is out of service is much reduced.

The S. N. C. F. is satisfied with the results obtained with the GG steel with a specified resilience U. F. of 2 kg/cm² but no definite comparison has yet been possible and the question is still under study, the quality of the steel being the main factor.

The English heat treated one piece steel wheels are markedly superior to the tyred wheels but their further use is restricted by their price.

On the S. N. C. B. the wheels tried under 10 vehicles showed the spreading of the tread on the side opposite the flange. A number broke in service and this lead to the withdrawal of all. The broken wheels showed they had been badly annealed leaving the steel with a course grain perlitic structure with too low resilience.

One piece wheels on carriages will be of interest when the quality of steel is right and the price low enough. From the C. F. F. experience, progress in steel manufacture may bring this about.

Wagons.

As regards chilled cast iron wheels, these are unanimously condemned by the European Railways by whom they have been replaced by the usual tyred wheels. There have been many cases of failure with these wheels in service and under repair and in particular shedding of large pieces of the tread and flange. The statistics of failures show how serious these defects have been. On the S. N. C. F. of 177 564 wheels in chilled cast iron put into service since 1946, 23 359 or 13 % had, as at 1-10-49, been taken out of service for defects.

Question 7. — *Do you use solid wheels on vehicles running at high speeds?*

The C. F. F. report their R. I. C. coaches with one piece wheels run up to 125 km/h. and those of the S. N. C. F. to 130.

Question 8. — *Do you use them on braked vehicles (braking on running surface, on brake drum, or on the wheel centres)? What material is used for brake shoes? What advantages and disadvantages have been established?*

In the above applications, the wheels are braked by ordinary blocks. The C. F. F. blocks in grey cast iron contain 10 % of steel.

Question 9. — *What metal is used for solid wheels (chemical analysis and physical characteristics)?*

Question 10. — *Do you use special methods of manufacture in order to obtain the appropriate characteristics of the metal in the different parts of the wheel?*

Table 25 gives particulars of the steels tried or used for carriage and wagon one piece wheels.

The results on the C. F. F. being interesting, we give the heat treatment used. The treads and flanges are given surface treatment to harden the surface.

All the solid wheels of the C. F. F. are given superficial heat treatment in order to give greater hardness to the tread.

The rolled non-alloyed steel wheels *a*) of the Table 25 and the rolled and pressed steel wheels *b*) of Table 25 are heated so that the rim is at a higher temperature than the body of the wheel. The wheel is then quenched in an oil bath. The hardness of the flange and tread is 280 to 310 Brinell equal to 100 to 110 kg/mm². The hardened layer is 35 to 40 mm deep. The special cast steel wheels *c*) in Table 25 made in Switzerland and put in service after the war were after rough turning heated to 930° C (held at this for 8 h.). They were then machined. The subsequent heat treatment was to heat to 900° for 4 h. The rim was then cooled by water spray for 12 min.; the boss and disc being prevented from cooling. After quenching, the wheels are annealed for 5 h. at 450/500° C. The tread and flange hardness is equivalent to 100 kg/mm². The depth of the hardened layer is 20 mm.

Question 11. — *Can the solid wheels which you use be re-profiled, by the depositing of metal, by turning, etc., and what are the thickness limits in each case?*

Question 12. — *In the case of wheels having flats do you repair on site by building up by welding and making good the tyre surface by grinding or turning?*

The S. N. C. F. wheels are 73 mm thick new and are re-turned down to the minimum of 30 mm.

The C. F. F. and Algerian Railways are the only Railways, judging from the replies received, which build up the *flanges* of both one piece and tyred wheels by electric welding currently.

The process as laid down on the C. F. F. is :

— turn to correct profile without touching the flange;

— preliminary heat to 120° C;

— build up by welding;

— reheat to about 150° C for rims of over 70 kg/mm²;

— cool slowly under cover and then turn up;

— hammer with copper mallet to prevent cracks.

In the case of *flats* the repair is done by grinding in a lathe.

Question 13. — *After several returnings are you able to retyre wheels which originally were solid wheels?*

The Railways as a rule tyre worn one piece wheels.

Question 14. — *List the defects such as shelling, scaling, radial cracks or others? Are these defects more or less frequent with solid than with tyred wheels?*

The C. F. F. have most experience with one piece wheels and state that the scaling and flaking recorded is not more than on tyres.

C. — TYRED WHEELS.

Question 15. — *What quality of metal of tyres (chemical analysis and physical characteristics, method of manufacture and especially type of heat treatment)?*

Question 16. — *What are the measures that you have adopted to reduce to a minimum the risk of loose tyres? (State of surface after machining, diameters of the wheel centres and tyres in contact before mounting, system of heating tyres, etc.). Do you weld at the rim to prevent loose tyres?*

The information received is like that given for steam locomotives (see 1st Part, Question 15).

The C.F.F. tyres are Siemens-Martin steel of the same characteristics as the metal of

TA

Administration	Kind of steel of wheels	Compositio					
		C	Mn	Ni	Si	Cr	Mo
BELGIUM *S. N. C. B.*	Wheels of rolled carbon steel.	0.66	0.64	—	0.41	—	—
FRANCE *S. N. C. F.*	GG steel wheels to specification n° 301.	—	1 max.	0.50 max.	0.50 max.	—	—
HOLLAND *Netherlands Railways*	Rolled steel wheels under test Siemens Martin and British Standard quality steel.	—	—	—	—	—	—
SWITZERL. *C. F. F.*	*Carriage wheels* : *a)* One piece wheels in unalloyed Siemens Martin steel.	0.6 appr.	—	—	—	—	—
	b) Rolled and pressed steel wheels in Siemens Martin steel supplied by « Bochumer Verein ».					Composition	
	c) Cast steel wheels. Alloy steel made in electric furnace.	0.45	1	—	1	—	—
American rolling stock common to several railways.	Chilled cast iron wagon wheels made in America.	Total 3 min. combined 0.90 max.	0.50 min.	—	—	—	—

the one piece wheel (see *a*). Table 25, Question 9, 70-85 kg/mm² steel. No heat treatment is given. Fig. 33 shows the lightened wheel and axle used under the light steel coaches.

Question 17. — *What are your specifications regarding the minimum thickness of tyres according to the load or maximum speed permitted for vehicles (minima both after repair and in service)?*

...e steel			Heat treatment	Mechanical characteristics required				
P	S	Various (individ.)		R kg/mm²	E kg/mm²	A %	K UF	△ Brinell
.05	0.05	—	—	—	—	—	—	240
.05 max.	— —	0.25 max.	—	70 min.	—	14 min.	2 min.	—
.05 max.	0.05 max.	—	—	79 to 87	—	13 to 11	—	—
P + S 0.1 max.		—	Rolling surface and flange surface hardened to R = 100 to 110 km/mm²	70 to 85	35	Measured on length 1 = 5d 12 min.	—	195 to 235
wn			Rolling surface and flange surface hardened to R = 100 kg/mm²	80 to 90	—	—	—	—
—	—	—	Rolling surface and flange surface hardened to 100 km/mm².	70 to 80	—	—	—	—
.35 max.	0.14 max.	—	—	—	—	—	—	—

Table 26 gives the regulations in force.

Question 18. — *When wheels have flats do you repair by building up by welding and making good the tyre surface by grinding or turning?*

Some Railways (Gafsa, Moroccan, Algerian) weld the tread as ordinary practice following the practice given for steam locomotives (1st Part, Question 18).

Question 20. — *Have you found with loco-*

TABLE 26.

Minimum tyre thickness on trailer vehicles.

Administration	Type of stock	Minimum thickness allowed	
		After repair (last turning)	in service (before withdrawal of tyre)
BELGIUM *S. N. C. B.*	RIC coaches	45	35
	Other coaches (receive the wheels of the former when withdrawn)	35	30
	Ordinary types of wagons.	30	25
	S or SS wagons	35	30
Bas-Congo to Katanga Railway	Wagons	—	35
DENMARK *State Railways*	Carriages and wagons of axle weight $<$ 10 t	—	(Thickness at edge) heel not included 25
	Carriages and wagons of axle weight 10 to 15 t . .	—	30
	Carriages and wagons of axle weight $\geqslant$ 15 t	—	35
FRANCE. *S. N. C. F.*	RIC or 130 (not barred) carriages and brake-vans (the latter are authorized to run at 130 km/h)	38	35
	Other GV bogie carriages and brakevans (or with axles) normally incorporated in fast and express trains	32	28
	Other GV coaches and brakevans with axles. Wagons and PV brakevans fitted with air brake	29	25
	PV wagons not fitted with air brake, loads $>$ 15 t .	25	23
	PV wagons not fitted with air brake, loads $\leqslant$ 15 t .	25	20
Société Générale des Chemins de fer Economiques. Breton System. Meter gauge	Carriages and wagons	28	23

TABLE 26.

Minimum tyre thickness on trailer vehicles *(continued)*.

Administration	Type of stock	Minimum thickness allowed — After repair (last turning)	Minimum thickness allowed — in service (before withdrawal of tyre)
Moroccan Railways	GV roller bearing fitted stock	35	31.5
	GV stock with ordinary boxes	33.5	30
	Braked wagons	35	30
	Unbraked wagons	30	25
Gafsa Railways	Carriages and wagons	32	27
Indochina Railways	Carriages and wagons	—	25
Damas-Hama and extensions Railways	Carriages and wagons	35	30
NETHERLANDS *Netherlands Railways*	Carriages	38	35
	Wagons	28	25
LUXEMBURG *Luxemburg Railways*	RIC carriages	—	35
	2 or 3 axle carriages and wagons with brakes	—	28
	Wagons without brakes	—	25
NORWAY *State Railways*	Carriages and wagons	—	25
SWITZERLAND *C. F. F.*	Carriages, brakevans and post cars with six months between overhauls	40	—
	Other carriages and wagons	35	—
	Wagons	30	—
Emmental-Burgdorf-Thun Railway	Carriages and wagons	35	—

motives that the lateral displacement of the axles influences tyre wear?

Question 21. — *Have you proved that lessening of hunting (particularly lessening the rotation of the bogie round its pivot) reduces tyre wear?*

Question 22. — *Have you tried or do you use independent wheels? What has been your experience with these wheels regarding tyre wear?*

No Railway so far has ascertained the effect of damping hunting movements has on the tyre wear of trailer vehicles.

Independent wheels have only been tried on the C. F. F. on one bogie vehicle with one piece wheels. The tyres wore very irregularly.

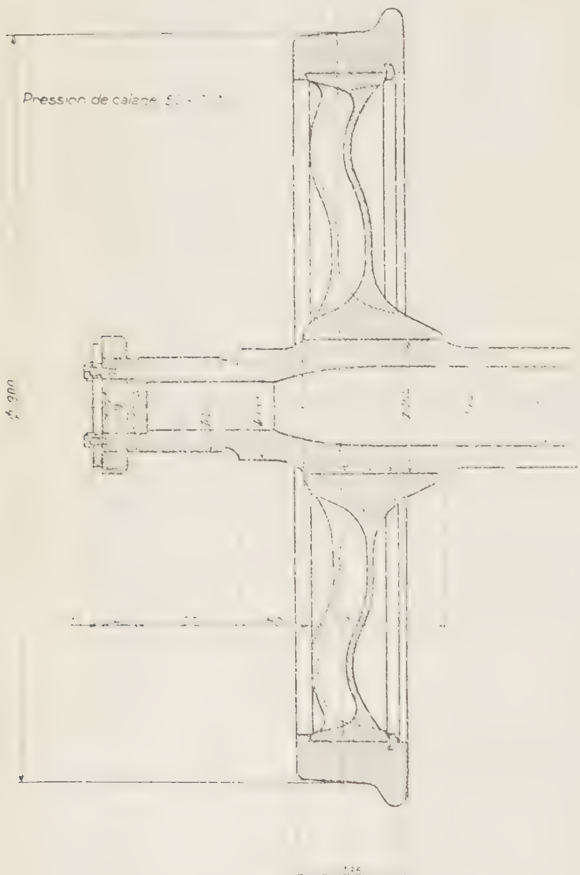


Fig. 33. — Application of tyre on one piece wheel type *b*, on hollow axle of light weight C. F. F. carriages. (Extract from C. F. F. WA 0641-44*a* drawing).

Pression de calage = pressed on at...

D. — AXLEBOXES.

a) Roller bearing boxes.

Question 23. — *Do you use roller bearings? If so, kindly say what results have been obtained regarding :*
a) *Number of hot boxes;*
b) *Maintenance costs;*
c) *State period between lubrication and inspection.*

Table 27 gives the application of roller bearing boxes to carriages and wagons.

Question 24. — *Have you found any difficulties due to the use of axle boxes of this type? Please indicate (fractures and wear of details, damage through rough shunting, etc.).*

a) The possible defects are overheating and breakage of details.

Overheating is very rare. The C. F. F. have had about 10 on 300 bogie vehicles put into service since 1937.

As regards *fractures*, most Railways report none or very unusual (Holland Algeria, S. N. C. B., Denmark, Norway).

The S. N. C. F. report on S. K. F. bearings :
- — broken bronze cage;
- — cracks in journals in line with the race on the inside occurring after 1 to 2 million km. These fractures raise the question of the diameter of the journal (120 mm journal on 48 t coach see Question 27) and the machining of the locking sleeve.

The C. F. F. reporting cracks on the inner ring state they are very rare;

b) *Maintenance costs.*

The C. F. F. point out that the repair costs are very low. In the case of a

TABLE 27.

Fitting of roller bearing boxes on trailer vehicles (carriages and wagons).

ADMINISTRATION	Vehicles fitted with roller bearings	Types of boxes fitted	Remarks
BELGIUM *S. N. C. B.*	60 4-wheel refrigerator wagons. Not applied to carriages.	Outside SKF boxes with 2 bearings with double row of rollers.	
DENMARK *State Railways*	Carriages, postal wagons and vans of recent construction. Test in hand on a number of wagons.	Outside SKF boxes.	
FRANCE *S. N. C. F.*	2 300 bogie vehicles. 1 750 high speed 4 wheel wagons (early vegetable and refrigerator wagons).	Outside SKF boxes with 2 bearings with double row rollers locked by taper sleeves.	See fig. 1
	50 48t-bogie wagons.	*Timken* outside boxes with one bearing, with double row of taper rollers fitted hot.	See fig. 3
	120 34t-bogie carriages.	*Timken* outside boxes with 2 bearings with single row of taper rollers, fitted with taper sleeve.	See fig. 34
	Trial on a suburban bogie carriage.	Nadella boxes with needles and ball bearing stops.	Test in hand, and still to be perfected.
Algerian Railways	Bogie metal coaches.	Outside SKF boxes with single bearing with double row of rollers *Timken* boxes with double bearing with single row of taper rollers.	Applied since 1947.

TABLE 27.

Fitting of roller bearing boxes on trailer vehicles (carriages and wagons) *(continued)*.

ADMINISTRATION	Vehicles fitted with roller bearings	Types of boxes fitted	Remarks
Moroccan Railways	Metal carriages.	Outside SKF boxes.	
Indochina Railways	28 t new carriages.	Outside SKF boxes with 2 bearings with double row of rollers.	
LUXEMBURG *Luxemburg Railways*	No stock fitted. They will be fitted on new carriages under construction.	Outside SKF boxes.	
HOLLAND *Netherlands Railways*	All carriages built since 1938.	Outside SKF boxes with 1 bearing with double row of rollers.	
	All wagons built since 1945.	Outside SKF boxes with 2 bearings with double row of rollers.	
NORWAY *State Railways*	A small number of vans and postal wagons.	Outside SKF boxes.	
SWITZERLAND *C. F. F.*	20 heavy carriages (37 to 42 t) with bogies.	Outside SKF boxes with one bearing with double row of rollers. (fig. 35)	This type of box is fitted on 158 RIC carriages.
	300 lightweight carriages with bogies.	d° (fig. 36)	
	500 hopper wagons 4 wheels (being supplied).	Outside SKF boxes with 2 bearing with double row of rollers.	
	450 4-wheel covered wagons	d° (fig. 37)	
Rhaetian Railways	New carriages		
Emmental-Burgdorf Thun Railway	28 t. new carriages	Outside SKF boxes with one bearing with double row of rollers forming spherical articulation.	

bogie coach repaired every year these costs amount to 100 Swiss francs per coach per annum. This includes the cost of taking the bearing apart every 6 to 8 years.

The S. N. C. F. consider the costs about the same as for plain bearings up to a mileage of 1 500 000 to 2 000 000 km. Above this there would be a tendency for defects in the boxes to occur much more frequently.

Table 28 gives particulars of the boxes used.

Question 26. — *What type of protection do you use against the penetration of dust and water into the interior of the box?*

Water and dust is prevented from getting into the boxes by labyrinths or grooves or by felt rings as on motor coaches.

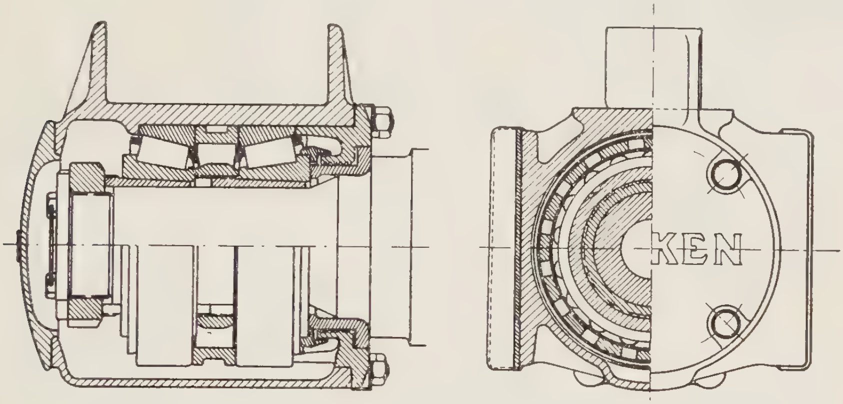


Fig. 34. — *Timken* double tapered roller bearing box (outside type), with single row of rollers, kept in position by split conical sleeves, oil lubricated (light carriages of the S. N. C. F.).

The Netherlands Railways give repair costs for two comparable boxes and the figure for the roller bearing boxes is much the lower (27.2 florins for a R 2 box with brasses per annum; 12 florins for a R 9 box with roller bearings). The other Railways are unable to express any opinion;

c) *Periods between lubrications and repairs.*

The boxes are lubricated at each repair; that is every year for the coaches (the grease is replaced every two years) and every 3 years for ordinary wagons (Netherlands, C. F. F.).

Question 25. — *What type of roller bearing box do you use (cylindrical, conical or roller bearings)?*

Figures 34, 35, 36, 37 show the different arrangements.

Question 28. — *What is the system of mounting the rollers on the journal? What are the advantages and disadvantages of the system used?*

The S. K. F. bearings are always fitted to the axle with a taper sleeve. The advantage over direct application to the journal is a larger manufacturing tolerance. The sleeve is split and within limits the play in the rollers can be taken up in consequence. It makes it much easier to take the bearing down as the outer threaded ring can take a nut by which to pull it off.

The *Timken* bearings are usually shrunk on hot or pressed on : there is a variant with tapered bushes.

Characteristics of the SKF roller bear
(classed by i

Catalogue number of bearing	Number of bearings per box	Projected length of the bore of the bearing in mm	Outside diameter of the bearing in mm	Min. dia, (1) of the bore of the bearing for shrinkage fit in mm	Diar of jo in r
Coaches with bogies					
22 324 K	1	86	260	120	1
I—37 602	2	73	220	120	1
I—35 156	2	80	240	120	1
I—37 906	2	86	260	130	120 a
I—37 906	2	86	260	130	1
I—37 906	2	86	260	130	1
22 328 K	1	102	300	140	1
4 *wheeled wagons*					
22 226 K	2	64	230	130	1
— d° —	— d° —	— d° —	— d° —	— d° —	— c
— d° —	— d° —	— d° —	— d° —	— d° —	— c
I—37 603	2	80	240	130	1
— d° —	— d° —	— d° —	— d° —	— d° —	— c
			Characteristics of TIMKEN roller		
153046/153101 fitted hot	1 double	94	259	120	1
154536/154511/154103 with conical sleeves	2 singles	81	262	130	120 a
FT 956/FT 952 FT 955/FT 952 with conical sleeves	2 singles	65	225	120	1

(1) Tapered bore when fastening effected by conical sleeves.

es and wagons
s of journals).

eel eter mm	Maximum speed of vehicle in km/h	Maximum axle load in t	Vehicles on which this type of bearing is fitted		
			Administration	Type	Number
00	125	10	*C. F. F.* (SWITZERLAND)	Coach 27 to 29 t	300
20	130 (designed for 160 km/h)	11.5	*S. N. C. F.* (FRANCE)	Coach 34 t	110
20	130	12	— d° —	Coach 36 t	2 195
20	130	15	— d° —	Coach 48 t	
—	120	10	DENMARK *State Railways.*	—	—
—	120	12	*Algerian Railways*	—	—
00	120	14	*C. F. F.* (Switzerland)	Coach RIC 37 to 42 t	20
50	100	15 and 16	*S. N. C. F.* (FRANCE)	Early vegetable and refrigerator wagons.	1 741
00	100	14	*Netherlands Railways.*	—	—
10	100	13.3	*S. N. C. B.* (BELGIUM)	Isothermos Wagons K.	60 450
—	100	16	*C. F. F.* (Switzerland)	Wagons T.	500 being delivered
00	80	18	*Netherlands Railways*	—	—
coaches :					
20	130	15	*S. N. C. F.* (FRANCE)	Coach of 48 t	50
20	130	15	— d° —	— d° —	
20	130 (designed for 160 km/h)	11.5	— d° —	Coach 34 t	115

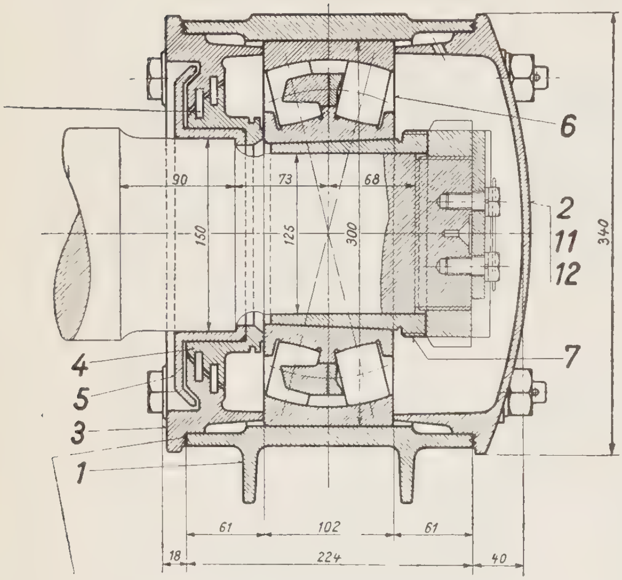


Fig. 35. — S. K. F. roller bearing box, outside type, with one double row of rollers, forming spherical articulation, fastened by split conical sleeve. Lubrication by grease and tightness obtained by labyrinth grooves, filled with grease. (R. I. C. carriages of the C. F. F. — Extract from W. A. 6231 C. F. F. drawing).

The S. N. C. F., having found cracks in the axles (see Question 24) with bearings held by tapered sleeves, is seeing if the cracks occur with the same frequency with hot shrunk bearings as with pressed on bearings. The conclusion of this investigation has not yet been formulated.

Question 29. — *Do you use special arrangements to prevent electric current passing through the roller bearings (current for traction or heating)?*

No Railways fit any device to prevent the return current passing through the roller bearings. On the C. F. F. coaches this current, which reaches 30 to 40 A per coach, has never caused any inconvenience.

b) **Boxes with plain bearings other than ordinary boxes with lubricator pads or packing.**

Question 30. — *Describe what types of axle boxes having bearings or brasses other than ordinary axle boxes do you use?*

Question 31. — *What is used for the lubrication of these axle boxes (grease or oil)?*

Question 32. — *What type of protection is used against the penetration of dust and water to the interior of these axle boxes?*

The Railways on carriages and wagons fit oil circulating boxes or mechanical lubricators of the following types:

Isothermos or Athermos: (S. N. C. B., Matadi-Léopoldville, Denmark, S. N. C. F., Algeria, Morocco, Luxemburg, C. F. F., Rhaetian);

Stemi-Friedmann: (S. N. C. B., S. N. C. F., C. F. F.);

Leonard: (S. N. C. B.).

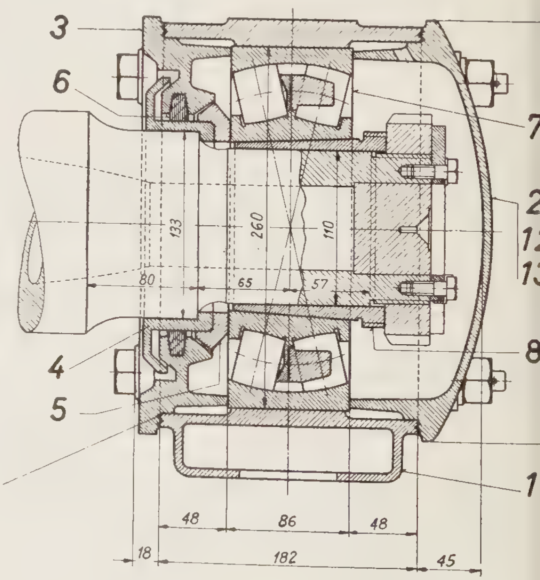


Fig. 36. — Same type S. K. F. roller bearing box as in Fig. 35, but with felt ring sealing for lightened C. F. F. carriages. (Extract from W. A. 6301 C. F. F. drawing).

The *Athermos* and *Friedmann* boxes have been described in the part dealing with locomotives and tenders (1st Part, Question 30).

c) **Improvement to ordinary boxes with brasses.**

Question 33. — *What improvements have you carried out to brasses and oil pads?*

— Oversize boring of the bearing face of the brass to facilitate the formation of the oil film (S. N. C. F., C.F.F. with constant oversize, S.N.C.B. with increasing oversize as the diameter is greater);

— suppression of grooving of the face of the brass to help the white metal to attach itself in favour of simple adhesion on a well tinned surface S. N. C. F.;

— reduction of thickness of the white metal to prevent it spreading (see Question 35).

Lubricator pads.

The S. N. C. F. has increased the discharge of oil from the pads by improving the wicks, the discharge having been increased from 85 gr/h. to 600 gr/h.

The C. F. F. has also increased the discharge of oil (number of strands in the wicks raised from 100 to 240).

These figures relate to coaches. As regards wagons the S. N. C. B. and Gafsa Railways report a return to the simpler packing which meets their requirements.

Question 34. — *What type of anti-friction alloy is used? Is there a preference for the use of anti-friction metal rich in tin, according to the type of vehicle (load and speed)?*

Question 35. — *Describe the method of applying the anti-friction metal (grinding, centrifugal, sintering, fritting, etc.) and the minimum thickness of the layer.*

See Table 29.

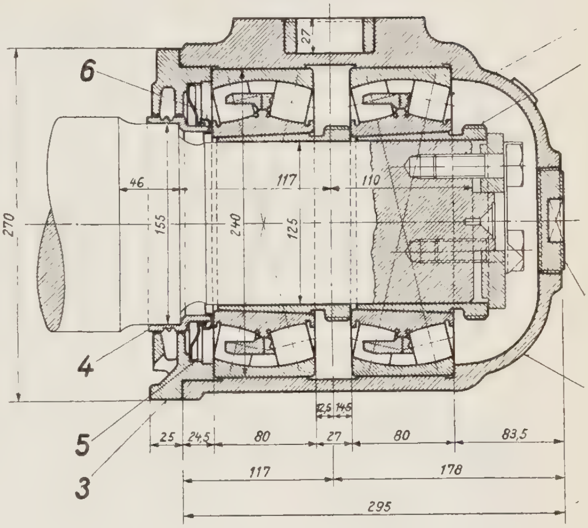


Fig. 37. — S. K. F. outside type double roller bearing box with double row of rollers fastened by split conical sleeves, grease lubricated, for wagons (Extract from W. A. 6021 drawing of the C. F. F.).

d) **Present tendency in the selection of the type of box.**

Question 36. — *Set out the different categories of locomotives and rolling stock, and the various types of service which govern the choice of the type of boxes to be adopted, showing the reasons.*

The principal replies received are as follows :

S. N. C. B. (Belgium).

All types of carriages.

The S. N. C. B. uses widely a box with plain brasses packed with waste. It is not intended to give up this design on new stock as it is simple and cheap.

Wagons.

Except on wagons on fast service (*Isothermos* wagons in particular) waste packed boxes continue to be preferred.

Mechanically lubricated axleboxes were used before the War on new stock and the application of roller bearings is under consideration for future stock.

TABLE 29.

Antifriction metal used on carriages and wagons.

ADMINISTRATION	Name of alloy	Composition % of the white metal					Thickness of normal layer in mm	Remarks
		Pb	Sb	Sn	Cu	Cd		
BELGIUM *S. N. C. B.*	M1	0	11	83	6		7	RIC carriages and metal express coaches.
	M4	74	15	10	1			Stopping train metal carriages
	M3	79.5	15	5	0.5			Wooden carriages and wagons.
DENMARK *State Railways*	—	84	16	—	—		10 maximum	
FRANCE *S. N. C. F.*	AP2	85	10	5			3	Used also for wagons. Tests are being made on bogie coaches with AE3 white metal with 78 % of tin.
Algerian Railways	AE1						4	Same metal as for locomotives.
Gafsa Railways	—	75	13	12	—			Adopted a year ago to replace AP2 metal. Great reduction in heating and better resistance to wear.
Moroccan Railways	AP2	85	10	5			3	Carriages and wagons.
NETHERLANDS *Netherlands Railways*		74	15	10	1		5.5 to 8 (according to type of box)	Carriages and wagons.
NORWAY *State Railways*			12	83	4	1	4	Carriages and wagons.
SWITZERLAND *C. F. F. and various systems*			13	80	7		5	Carriages and wagons.

Denmark.

Coaches.

New stock is fitted with roller bearings.

Wagons.

New wagons are fitted with *Athermos* boxes.

S. N. C. F.

Main line coaches.

Coaches for international services and for a number on their own lines will be fitted with roller bearings so as to cut out as far as possible heating which in international service has unfortunate repercussions.

Stopping train and suburban vehicles.

These vehicles run relatively short distances and in consequence the plain brass with pad is preferred.

Wagons.

In principle, new wagons are fitted with ordinary boxes. A test is being made of mechanical lubrication on high capacity wagons (open wagons with 29 ton tare useful load). A test is also in hand on high speed wagons (early vegetable and refrigerator wagons).

Holland.

The Netherlands Railways, having had good results from outside roller bearings since 1927, now intend to fit them to all wagons to be built.

Norway.

Roller bearings will be fitted to all new vehicles.

C. F. F.

Coaches and wagons of all classes.

All vehicles, carriages, restaurant cars, brake vans, and recently built wagons have roller bearing axleboxes. Vehicles under construction will also be fitted. In addition the C.F.F. is fitting them to 58 R. I. C. coaches in place of plain bearings with mechanical lubrication.

The arguments in favour of this policy, in spite of an increase of 40 to 50 % in the cost price, are:

— suppression of hot boxes;

— very low repair costs;

— no supervision nor inspection in service.

The tendency on the Luxemburg, Algerian and Moroccan Railways is to fit roller bearings. On these Railways *Athermos* boxes are also fitted, as on the Indo-China Railways.

E. — WEAR RESISTING AND ANTI-FRICTION METALS.

Question 37. — *What are the details, in your opinion, the wear of which limits the mileage between repairs?*

The replies show that the wear of the tyres and running gear govern the mileage between repairs. The C. F. F. point out that the wear of tyres is the determining factor between two repairs as the stability after a certain wear becomes less good and sometimes even uncomfortable for the passengers.

Question 38. — *What materials are used to reduce the wear of details subjected to friction (axle box guides, various joints, etc.).*

Question 39. — *What methods have you adopted to make good worn details (e. g. fitting washers or bushes at joints, using easily replaceable wearing portions, etc.)?*

Coaches.

The guides on the horns are usually cast iron and the boxes fitted with steel liners but the widely extended trials of manganese steel for the two rubbing faces must be noted (S. N. C. F., Netherlands). The pins and links of the spring gear are as a trial being made of manganese steel (S. N. C. F.), though as a general rule the pins are case hardened.

Wagons.

Wear packing plates are not used.

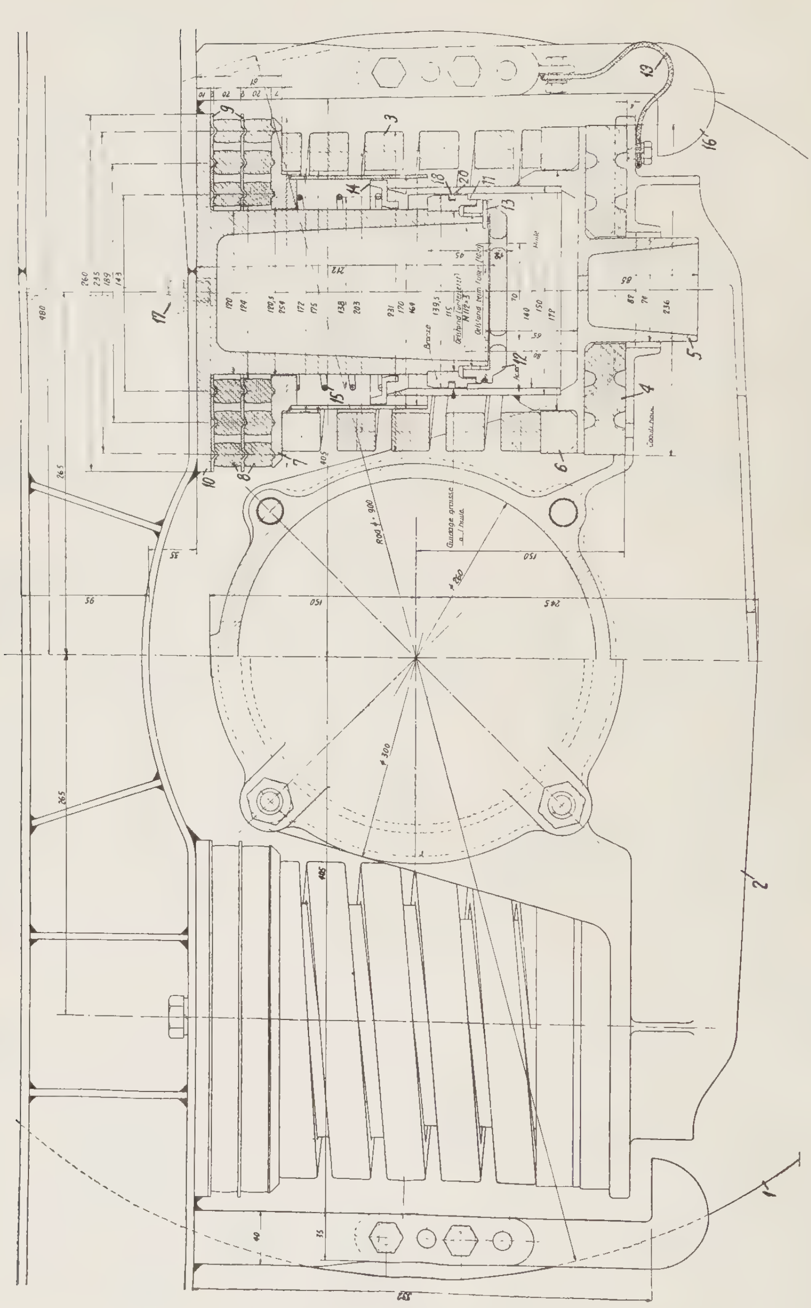


Fig. 38. — Primary suspension and frictionless guidage of axles under lightened steel stock of C. F. F. (Extract from C. F. F. drawing 98938)

3. helical supporting spring. — 4. Seating in rubber of the spring. — 8. Batra ring in rubber inserted between the spring and the bogie frame. — 17. Air evacuated from the oil snubber. — 19. Metal tape for shunting the india rubber suspension to earth the frame, assuring the return of the heating current.

Question 40. — *Have you adopted any special arrangements to avoid reciprocal friction between the different details (e. g. guiding by articulated links on silent block, etc.)?*

Only the C. F. F. report the introduction of the arrangement in their lightened vehicles which does away with the axlebox guides. This differs from that fitted to the electric locomotives described in the 2nd Part, Question 40. Figure 38 shows that the connection of the axle box to frame is made horizontally by rubber blocks which serve as the lower support of the combined coiled spring and snubber providing the vertical springing. These blocks work in shear and allow some horizontal displacement of the axle. A general view of the bogie of these coaches is given in figure 39.

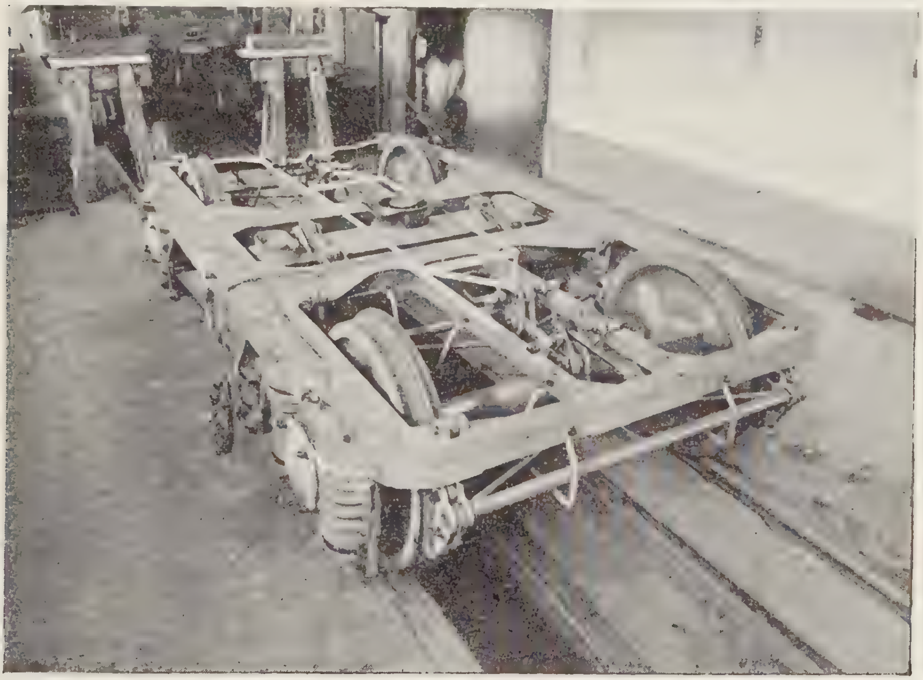


Fig. 39. — Bogie of C. F. F. lightened vehicle.

Question 41. — *Do you use with spring suspension details any protection devices on the parts subjected to friction (supports for the adjusting spring links, buckles, etc.)?*

The supports of the spring hangers of the C. F. F. coaches are fitted with anti-wear liners held in place by two spot welds. The rod is made of case hardened steel (180 kg/mm²) and the liner of heat treated steel of 140 kg/mm².

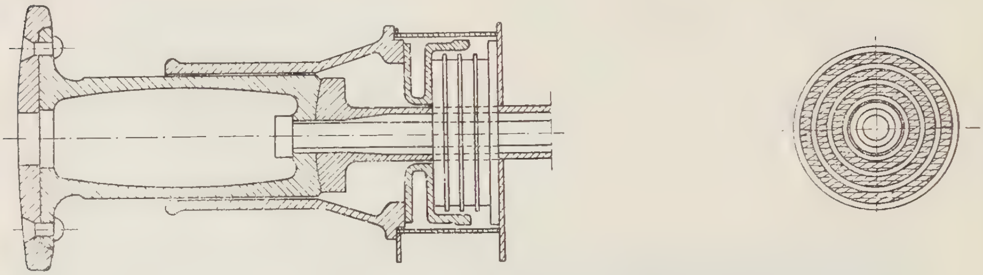
F. — SPRINGS.

Questions 42 to 46.

As regards fabrication, use, and behaviour in service of the various steel springs (laminated and coiled), please see the corresponding chapter relative to steam locomotives (1st Part).

Carriage buffer with anti-shock reinforced rubber spring.

Fig. 40



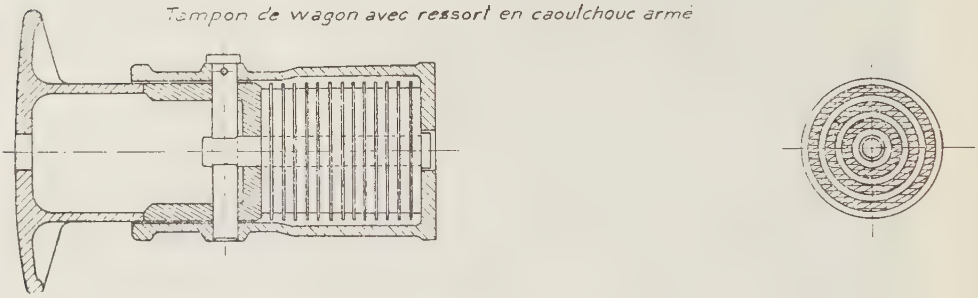


Fig. 41

Wagon buffer with reinforced rubber spring.

Carriage draw gear with reinforced rubber spring.

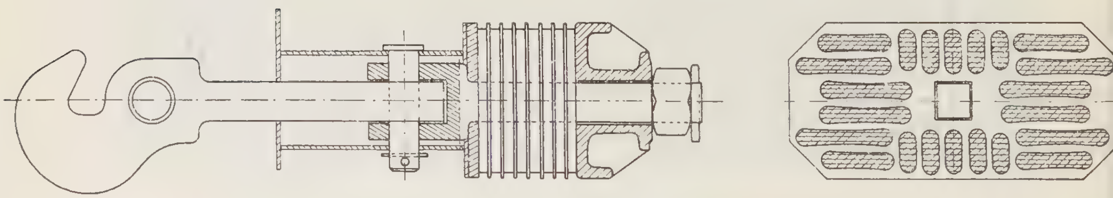
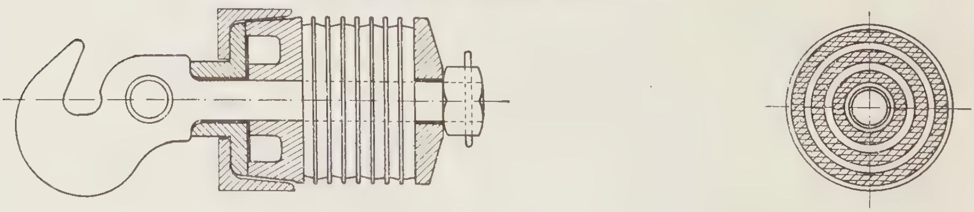


Fig. 42

Wagon draw gear with reinforced rubber spring.

Fig. 43



Figs. 40 to 43. — Application of rubber springs to buffer and draw gear of S. N. C. F. carriages and wagons.

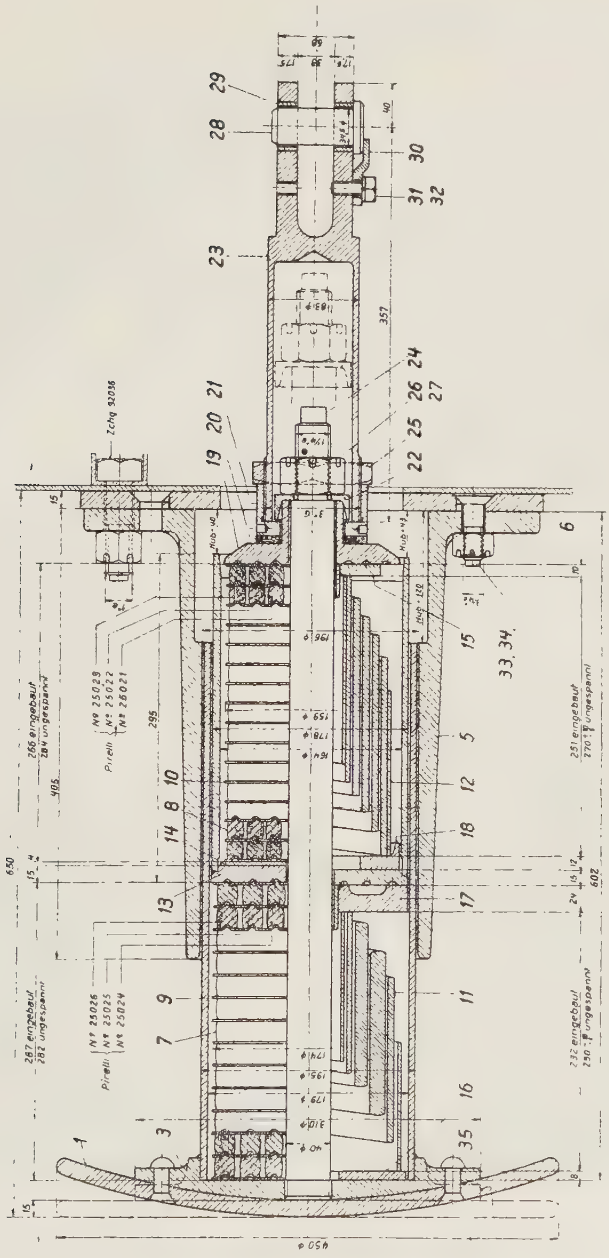


Fig. 44. — C. F. F. buffer plunger compensated with rubber or volute springs. (Extract from C. F. F. drawing 91543). Volute springs only used during the war.

Defective springs are rare on coaches. On wagons they are more frequent and are more often due to shocks in the shunting yard. The methods to reduce them are given in the first part.

As regards *coiled springs* becoming general on high speed bogies, some Railways are replacing the round section by the square or rectangular. This is so on the lightened vehicles of the C. F. F. and on the Norwegian Railways. These Railways find the square section springs break much less frequently than the round section ones, the fractures of which begin frequently on the surface along the fins left by rolling.

For this reason the S. N. C. F. and other Railways insist on the steel bars for coiled springs being scaled and polished before rolling.

Question 47. — *Do you use rubber springs (for suspension, for shock and for drawgear, etc)? What are the results obtained?*

a) *Suspension.*

The S. N. C. F. have made tests of rubber springs in the suspension fitting them under the coiled springs, and under the bogie pivots to damp vibration. The records do not show any marked improvement and the arrangement has not been extended. The C. F. F., on a lightened vehicle, have replaced the coiled springs in the primary suspension by bell-shaped rubber springs made by *Pirelli*. The results so far are not considered conclusive;

b) *Buffing and draw gear.*

On trailer stock rubber buffing and draw springs are widely used (S. N. C. B., S. N. C. F., Algeria, Morocco, C. F. F.). The following arrangement on the S.N.C.F. is given as an example :

— on coaches, the rubber springs are used as the final load carrying spring after compressing the laminated or coiled spring of the buffer (see fig. 40). This gives a strongly decreasing flexibility at the end of the buffer travel;

— on wagons, Spencer Moulton rubber springs (see fig. 41) with steel dividing plates replace the volute springs now no longer fitted on modern stock.

Figures 42 and 43 show applications of rubber armoured drawbar springs to modern carriages and wagons of the S. N. C. F.

Figure 44 shows the arrangement adopted by the C. F. F.

The results obtained with the use of rubber springs with steel dividing plates in the buffing and draw gear are stated as very satisfactory by the S. N. C. F. and C. F. F.

However, the Netherlands Railways have made a less favourable comment. A long comparative test between volute and reinforced rubber springs on wagons has not shown the superiority of the rubber springs. This Railway does not expect to use them in future as they cost three times the price of steel springs.

Belgium, the international cross-roads.

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